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NITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 866

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. August 24, 1920

PICKERING SPRAYS

By

F. C. COOK, Physiological Chemist
Insecticide and Fungicide Laboratory

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By F. C. Cook,[1] *Physiological Chemist,*
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INTRODUCTION.

When, in 1916, the price of copper sulphate (bluestone or blue vitriol) rose to 25 and 30 cents a pound in certain parts of the country, the United States Department of Agriculture began to receive many inquiries as to the possibility of controlling certain fungous diseases of fruits and vegetables, either by using sprays other than those containing copper or by reducing the amount of copper sulphate used per given amount of spray. Past work having failed to show any fungicides which could replace the copper sprays for certain important plant diseases and the search for a new spray appearing rather unpromising, it seemed advisable to seek a copper spray which was more effective per unit of copper than the standard Bordeaux mixture and at the same time not so caustic as to injure vegetation. Accordingly, the Bureau of Chemistry, in cooperation with the Bureau of Plant Industry and the Maine Agricultural Experiment Station, undertook an investigation to determine the comparative efficacy of the so-called Pickering sprays, which had been

[1] The author wishes to express his appreciation of the cooperation he received from J. K. Haywood, Bureau of Chemistry; from W. B. Clark, H. A. Edson, L. H. Evans, W. A. Orton, J. W. Roberts, E. S. Schultz, C. L. Shear, M. B. Waite, E. Wallace, and R. B. Wilcox, of the Bureau of Plant Industry; from Donald Folson, W. A. Morse, G. B. Ramsey, and C. D. Woods, of the Maine Agricultural Experiment Station; and from Franklin Chambers, Superintendent of Whitesbog, Hanover Farms, N. J., and J. E. Sullivan, Superintendent of Aroostook Farm, Maine.

tested to a limited extent in England, where laboratory tests indicated that they were superior to the Bordeaux sprays (3, 4).[1] Pickering sprays, sometimes called Pickering limewater sprays, are prepared by mixing saturated limewater with dilute solutions of copper sulphate, and contain their copper in the form of basic copper sulphates.

RESULTS OF PREVIOUS INVESTIGATIONS.

FUNGICIDAL ACTION.

Bedford and Pickering (3, 4) claimed that the fungicidal action of Bordeaux depends upon the re-formation of copper sulphate by the action of carbon dioxid from the air. They believed that the excess of lime present in Bordeaux is carbonated before the copper, and held that since the fungicidal action depends upon the carbonation of the copper and the re-formation of copper sulphate, the excess lime of Bordeaux delays the action. These investigators stated that basic sulphates of copper are produced by the action of lime on copper sulphate, and that the basic sulphates vary in composition according to the proportions of lime and copper used. Most of the basic sulphates are complex, and contain, in addition to the elements essential in a basic sulphate of copper, calcium sulphate or calcium oxid, sometimes both. For present purposes the calcium sulphate in these compounds need not be considered. The basic sulphates of copper, being practically insoluble in water, can of themselves have little or no fungicidal action, but when exposed to the carbon dioxid of the air they are gradually decomposed to form copper carbonate and copper sulphate. The copper carbonate, being insoluble, is incapable of energetic action. According to Bedford and Pickering, the substances which are formed in the so-called Pickering sprays by the action of lime on copper sulphate, omitting the calcium sulphate present, are:

Formula A.— 4 CuO, SO_3 (or 10 CuO, 2.5 SO_3).
Formula B.— 5 CuO, SO_3 (or 10 CuO, 2 SO_3).
Formula C.— 10 CuO, SO_3.
Formula D.— 10 CuO, SO_3, 3 CaO (ordinary Bordeaux).
Formula E.— CuO, 2 CaO (or 10 CuO, 20 CaO) (existence doubtful).
Formula F.— CuO, 3 CaO (or 10 CuO, 30 CaO).

The following equations [2] express the changes which these substances undergo when acted upon by carbon dioxid in the laboratory, the equations being so arranged as to represent the results when the same initial weight of copper sulphate is taken in each case. The

[1] The figures in parenthesis throughout this bulletin refer to the bibliography on page 46.

[2] The formulas are expressed in terms of the English imperial gallon, which weighs 10 pounds, while the U. S. gallon weighs 8.3389 pounds, and the English fluid ounce, which is equivalent to 1/20 pint, or 28 cc., while the U. S. fluid ounce is equivalent to 1/16 pint, or 29.6 cc.

actual weight of pure lime (calcium oxid) and the approximate volume of clear limewater which would contain this lime are also given in each case.

FORMULA A (4 CuO, SO_3).

Proportions required: Crystallized copper sulphate 1, lime 0.169 (6:1); or copper sulphate 1 ounce,[1] limewater 134 ounces.[2]

REACTION.

(A) 10 $CuSO_4$ + 7.5 CaO = 10 CuO, 2.5 SO_3 + 7.5 $CaSO_4$

(A′) 10 CuO, 2.5 SO_3 + 3.75 CO_2 = 3.75 $(CuO)_2$, CO_2 + 2.5 $CuSO_4$

This formula represents a 25 per cent re-formation of copper sulphate.

FORMULA B (5 CuO, SO_3).

Proportions required: Crystallized copper sulphate 1, lime 0.18 (5.56:1); or copper sulphate 1 ounce,[1] limewater 143 ounces.[2]

REACTION.

(B) 10 $CuSO_4$ + 8 CaO = 10 CuO, 2 SO_3 + 8 $CaSO_4$

(B′) 10 CuO, 2 SO_3 + 4 CO_2 = 4 $(CuO)_2$, CO_2 + 2 $CuSO_4$

This formula represents a 20 per cent re-formation of copper sulphate.

FORMULA C (10 CuO, SO_3).

Proportions required: Copper sulphate 1, lime 0.203 (5:1); or copper sulphate 1 ounce,[1] limewater 161 ounces.[2]

REACTION.

(C) 10 $CuSO_4$ + 9 CaO = 10 CuO, SO_3 + 9 $CaSO_4$

(C′) 10 CuO, SO_3 + 4.5 CaO = 4.5 $(CuO)_2$, CO_2 + $CuSO_4$

This formula represents a 10 per cent re-formation of copper sulphate.

FORMULA D (ORDINARY BORDEAUX MIXTURE).

Proportions required: Equal weights of copper sulphate and lime; or copper sulphate 1 ounce,[1] limewater 800 ounces.[2]

REACTION.

(D) 10 $CuSO_4$ + 44 CaO = 10 CuO, SO_3, 3 CaO + 9 $CaSO_4$ + 32 CaO

(D′) 10 CuO, SO_3, 3 CaO + 7.5 CO_2 =

4.5 $(CuO)_2$, CO_2 + 3 $CaCO_3$ + $CuSO_4$

This formula represents a 10 per cent re-formation of copper sulphate.

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[1] Avoirdupois. [2] Fluid imperial ounces.

The results of their laboratory tests, in which the re-formed copper sulphate was determined after carbon dioxid had been passed through the various basic sulphates, led Bedford and Pickering to believe that the Formula A spray, re-forming 40 per cent of the copper sulphate, was from 12 to 15 times as effective as ordinary Bordeaux mixture (Formula D), which re-formed 2.8 per cent of the copper sulphate, and that the Formula C spray, re-forming 22 per cent of the copper sulphate, was about 8 times as effective as the standard Bordeaux (Formula D).

These investigators (4) stated also that, "the efficacy of a fungicide must not be estimated by the amount of copper contained in it, but by the amount which becomes soluble and therefore available for fungicidal action. Nor should the efficiency of a spray be judged by the visible deposit left on the leaves, for even if it were composed entirely of copper compounds it does not follow that it would be more efficacious than some other deposit which might be invisible. In most cases the deposit consists largely of material which is quite inefficient and may be detrimental to fungicidal action, as is the lime which constitutes four-fifths of the deposit visible after spraying with ordinary Bordeaux mixture." Later they reported that the idea that the fungicidal action of standard Bordeaux spray does not commence until several days after its application had been definitely disproved, and that the effects of the application of Bordeaux do not become visible at once because time is necessary for the decay of the tissues, which is the case even when a copper salt in solution is applied, but that the excess of lime in ordinary Bordeaux causes the fungicidal action to proceed more slowly. Pickering, however, believed that in ordinary or standard Bordeaux made with milk of lime the copper reacts and undergoes on the tree the changes given under the reaction for Formula D (p. 3).

Swingle (23), Sicard (22), Bell and Taber (5), Vermorel and Dantony (24), and others have discussed the chemical composition of standard Bordeaux sprays, which are prepared by mixing a solution of copper sulphate with milk of lime. These two ingredients are brought together in various ways, and the manner of mixing undoubtedly affects the chemical and physical properties of the spray. The details of the many theories covering the chemical reactions which take place when copper sulphate and calcium hydrate are mixed need not be considered here.

Opposed to the belief held by Pickering and others that the copper of Bordeaux is slowly made active by the carbon dioxid of the air are the statements by Lutman (14) that Bordeaux mixture is fungicidal immediately upon application. This writer considers that the lime particles in Bordeaux have fungicidal properties. Swingle (23), in 1896, advanced a series of ideas as to possible methods

whereby the copper of Bordeaux prevented fungous infection of plants. Gimingham (10) and Barker and Gimingham (1, 2) do not accept the theory of Pickering that the carbon dioxid of the air renders the copper soluble in Bordeaux, but believe that the permeable cell walls of the spores absorb copper from insoluble copper compounds in the spray.

In 1902 Clark (8) stated that the process of rendering soluble portions of the copper hydrate ($Cu(OH)_2$) of Bordeaux mixture, which under orchard conditions is of fungicidal value, is accomplished chiefly by the solvent action of the fungus spores, which have the power to dissolve enough copper to kill themselves. The host plant has a certain power of dissolving copper hydrate deposited on its leaves.

PHYSICAL PROPERTIES.

A spray must so distribute the copper compound it contains as to completely cover the trees or plants in a thoroughly uniform manner and must possess the proper adhesive properties. If either of these physical properties is lacking, the spray fails to accomplish its purpose.

Various settling tests with Bordeaux prepared in different ways have been made, and numerous adhesives have been tried. Hawkins (12), who gives a detailed description of such tests, states that Pickering sprays remain in suspension better than ordinary Bordeaux. Lutman (13), in his data, which include descriptions of the precipitation membranes formed in freshly prepared Bordeaux, states that the slow settling properties and the presence of the precipitation membranes in freshly prepared Bordeaux are in a great measure responsible for its superiority as a protective agent against fungous diseases. This investigator studied the areas covered by 1 cubic centimeter of the various sprays tested on glass slides, as a result of which he concludes that "very dilute solutions such as Pickerings possess a greater covering power for the amount of materials used."

The physical properties of the Pickering, or limewater Bordeaux, sprays are not described by Pickering, but have been studied by Lutman (14) and by Butler (6). Butler, who has investigated the formation of sphere crystals in various copper sprays, claims that the rate at which they form depends on the concentration and temperature of the mixture. Both of these investigators state that the film membranes of the Pickering sprays do not deteriorate as do those in a regular Bordeaux spray, and that the sphere crystals are not formed in Pickering sprays, even after long standing. This is an important point, as the formation of such crystals signifies a breaking down of the precipitation membranes and a deterioration of the spray.

GENERAL CONSIDERATIONS.

Butler (7) states that freshly prepared Pickering spray has a light-blue color, which becomes deep blue on standing. He found a neutral or acid Bordeaux, such as the Pickering sprays, to act more quickly than ordinary Bordeaux, and reported that the Pickering spray was less injurious to grapes than ordinary Bordeaux. He states that the toxic value of the unit copper is the same in acid, neutral, and alkaline Bordeaux, but is more available for immediate action in the Pickering than in the ordinary Bordeaux sprays.

According to McAlpine (15), who compared the results of Pickering with those of standard Bordeaux sprays on apple trees, the two varieties are equally effective in controlling black spot (*Fusicladium dendriticum*). The limewater Bordeaux adhered just as well as the standard Bordeaux, and had the additional advantages of being free from gritty particles, of acting at once on the spores of the fungus, and of containing a much smaller percentage of bluestone. The check trees gave 92.5 per cent of good fruit, indicating that the black spot was not sufficiently severe to give definite results.

F. de Castella (9) states that Pickering's claims concerning the greater efficacy of the limewater sprays are not borne out in practice. He reports that after extensive trial they have been found decidedly inferior to 2 per cent Bordeaux and that the use of Pickering sprays can not be recommended. He considers the Woburn or Pickering paste sold in England to be satisfactory but not superior to Bordeaux. The greater solubility of the tetra-cupric sulphate seems to be a defect rather than an advantage according to this writer, for the reason that, while more active at first, it is removed by heavy rains more readily than the ordinary Bordeaux deposit, thus rendering the duration of the protection insufficient. No data are given by this writer to substantiate his claims.

PURPOSE OF PRESENT INVESTIGATION.

If the results obtained by Pickering in the laboratory in England hold true under field conditions in America, it is obvious that a great saving in copper in this country may be effected. This investigation was planned, therefore, for the purpose of outlining a practical method of preparing a copper fungicide which would be more effective per unit of copper than standard Bordeaux. The experiments were conducted with the following primary objects in view:

(1) To determine whether sprays made in accordance with the various Pickering formulas (p. 3) were effective when applied under American field conditions.

(2) To ascertain how much copper in the form of the different Pickering formulas is required per given quantity of spray to insure effective control of fungous diseases.

(3) To compare the fungicidal values of certain of the more promising Pickering sprays with those of standard Bordeaux mixture per unit of copper.

(4) To determine the injurious action of the more promising Pickering sprays on various kinds of vegetation as compared with that of standard Bordeaux.

(5) To compare the adherence of Pickering sprays with that of standard Bordeaux.

PREPARATION OF SPRAYS USED.

Pickering sprays made according to Formulas A and C (p. 3) were used in such proportions that the finished sprays prepared by Formula A would contain the equivalent of 0.64, 0.38, 0.13, and 0.065 per cent of copper sulphate, and those prepared by Formula C, 0.36, 0.23, and 0.115 per cent of copper sulphate. In making the stock solutions of limewater and copper sulphate these directions, outlined by Bedford and Pickering (4), were followed:

Dissolve the copper sulphate by suspending it in a piece of sacking, near the top of the water, in a wooden or earthenware container. Place not less than 2 or 3 pounds of some good quicklime (CaO) in a wooden container, slake with a little water, and add the desired amount of soft water. After making a smooth paste, add water, stir the lime and water two or three times, and let settle. Cover the container. Carbonate of lime found on top of the water does no harm. Run off the desired amount of the clear limewater, and mix with the required amount of copper sulphate solution. Test to be sure that all the copper has been combined with lime, and dilute to the required volume with water. To test for free copper, put a few drops of a solution of ferrocyanide of potash in a white saucer with water and drop into this some of the clear liquid obtained after the limewater Bordeaux has settled. If a brownish-red coloration appears, it indicates that copper remains in solution, a little more limewater must be added, and the solution retested.

To prepare Pickering (A)[1] sprays containing in the finished product the equivalent of—

0.64 per cent copper sulphate: Mix enough of the stock solution of copper sulphate (prepared so that 1 gallon is equivalent to 1 pound of copper sulphate) to obtain 2 pounds, 10.7 ounces of crystallized copper sulphate with 42.88 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.38 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 1 pound, 9.3 ounces of crystallized copper sulphate with 25.47 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.13 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 8.67 ounces of crystallized copper sulphate with 8.71 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.065 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 4.33 ounces of crystallized copper sulphate with 4.36 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

[1] Throughout this bulletin capital letters in parenthesis following "Pickering" indicate the formula used in making the spray.

To prepare Pickering (C) sprays containing in the finished spray the equivalent of—

0.36 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 1 pound, 8 ounces of crystallized copper sulphate with 38.98 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.23 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 15.3 ounces of crystallized copper sulphate with 18.52 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.115 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 7.7 ounces of crystallized copper sulphate with 9.26 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

Samples of water used in the various localities for the preparation of Pickering and Bordeaux sprays, analyzed by the Water Laboratory of the Bureau of Chemistry, contained very little lime or any other constituent that might interfere with the preparation of sprays, such as the Pickering sprays, which are made according to definite formulas and are said to depend for their activity on the presence of definite compounds, the basic sulphates of copper. According to the tests of Bedford and Pickering (3, 4), slight variations in the amounts of limewater employed result in the formation of different basic sulphates of copper, each of which functions as a fungicide in a characteristic way.

In slaking lime it is important to add just enough water to make it heat, after which water is added slowly to keep the lime from burning. When the reaction nears completion more water is added to make a paste. Finally, when the total amount of water required has been added, the solution is stirred to form saturated limewater.

RESULTS OF INVESTIGATION.

POTATOES.

Blight Control and Yield.

PICKERING AND STANDARD BORDEAUX SPRAYS IN 1916.

Six acres of Green Mountain potatoes in northern Maine (near the Aroostook Farm at Presque Isle) were selected for these experiments. As the sprayer was made to spray four rows at a time, the field was divided into four-row plats which, in turn, were subdivided into 200-foot lengths. Since the field was 800 feet long, four subdivisions were made in each group of four rows. A certain spray was applied to the first and third 200-foot plats, another one to the second and fourth 200-foot plats, etc. Thus each spray was applied to one plat in the front and to one in the rear of the field. The plats were so arranged that each four-row plat where any particular spray was being tested had a four-row plat of Bordeaux-sprayed potatoes on one side and a four-row check plat on the other.

Seven Pickering sprays were tested. Four (those used on plats 1, 2, 3, and 4) were made according to Formula A, while three (those

used on plats 5, 6, and 7) were made by Formula C. All the Pickering sprays were applied with a hand-pump apparatus on July 19 and August 2, 10, and 17. Bordeaux was applied on these days, and also on July 26. Thus the Pickering sprays were applied four and the Bordeaux five times. Readings for blight, both early and late, were made by three observers working independently, those for the late blight (*Phytophthora infestans*) being made on the two middle rows of each plat. The average figures obtained from two observations by each of these individuals are recorded, in terms of the estimated percentage of the total foliage infected, in Table 1. The potatoes from the several plats were picked up separately and weighed, the yield results thus obtained being given in Table 1.

TABLE 1.—*Effect of various sprays on blight and yield of potatoes (northern Maine, 1916).*

Plat No.	Spray used.	Copper sulphate in spray used.	Early blight.		Late blight.		Yield of tubers.[1]	
			Front of field.	Rear of field.	Front of field.	Rear of field.	Front of field.	Rear of field.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
.....	Bordeaux, 5–5–50	1.25	52	59	7	4	1,189	1,026
6	Pickering (C)	.115	67	73	40	5	1,165	957
Check			66	80	60	7	1,202	1,009
5	Pickering (C)	.23	64	78	43	5	1,221	963
.....	Bordeaux, 5–5–50	1.25	59	78	5	2	1,225	1,027
4	Pickering (A)	.065	63	86	53	6	1,170	915
Check			68	83	53	7	1,189	957
3	Pickering (A)	.13	65	78	13	5	1,187	901
.....	Bordeaux, 5–5–50	1.25	50	41	7	2	1,252	1,260
7	Pickering (C)	.36	61	58	36	6	1,283	1,260
Check			67	68	54	21	1,309	1,335
1	Pickering (A)	.64	64	55	27	4	1,260	1,426
.....	Bordeaux, 5–5–50	1.25	56	58	4	3	1,276	1,386
2	Pickering (A)	.38	63	61	21	7	1,313	1,208
Check			59	64	21	12	1,220	1,190
2a	Pickering (A) and rosin-fish-oil soap.	.38	72	70	5	3	1,179	1,016

[1] Determinations were made on 200-foot depth of field, four-row plats.

The blight in 1916 was not severe. The late blight on the potatoes under observation was very irregular, being marked in certain parts of the front of the field, particularly on the check plats, while the rear showed but little. On August 24 the vines in plat 1 and in those sprayed with Bordeaux were green, while those in all the other plats had died.[1] The best results for the control of late blight (*Phytophthora infestans*) on potatoes were obtained with standard Bordeaux, 5–5–50. The average estimated percentage of late blight on all of the plats sprayed with Bordeaux was $4\frac{1}{4}$, the extremes being 2 and 7.

The average yield for all of the plats sprayed with standard Bordeaux was 1,205 pounds of tubers, and for the check plats 1,176 pounds. Plat 1, sprayed with the Pickering (A) spray, containing 0.64 per cent of copper sulphate, averaged 1,343 pounds of tubers, and showed 27 and 4 per cent of blight in the front and rear portions

[1] A portion of this field was sprayed commercially by the owner, starting with a Bordeaux, 4–4–50, and finishing with a Bordeaux, 7–7–50 or 8–8–50. Neither the length of life of the vines nor the yield was increased by this treatment.

of the field, respectively. Plat 2a, receiving the Pickering spray which contained 0.38 per cent of copper sulphate and was mixed with rosin-fish-oil soap, showed 5 and 3 per cent of blight, and a yield of 1,098 pounds, while plat 2, receiving the same spray without the soap, showed 21 and 7 per cent of blight, and a yield of 1,261 pounds. Plat 3, receiving Pickering spray with an 0.13 per cent copper sulphate content, showed 13 and 5 per cent of blight, while plat 7 gave 36 and 6 per cent for blight. All the Pickering-sprayed plats were next to a check plat, while those receiving the Bordeaux were protected by sprayed plats on each side.

No rotten tubers were found on any of the plats. As is often the case, some variation occurred in the yields from different portions of the field. The vines of the check plats were not injured by driving through the plats, a factor of some importance in view of the fact that the spray cart was driven twice through some of the sprayed plats and four times through others when each spray was applied.

It is interesting to note that the average yields of the Pickering-sprayed plats just discussed varied with the percentage of copper sulphate present in the spray. The increased yield of the sprayed vines over that of the unsprayed vines was small, because of the dry weather and the early date at which the vines died.

The weak Pickering sprays (containing 0.23 per cent of copper sulphate or less) did not give satisfactory blight readings or results for yield. While the 0.64, 0.38, and 0.36 per cent copper sulphate Pickering sprays gave little indications of controlling the late blight in the front plats, they showed some control on the rear plats, and all the yields were satisfactory. No differences in the action of the Pickering (A) and Pickering (C) sprays were noticed. The copper in these sprays did not appear to be 12 times as effective as that in the standard Bordeaux sprays, but per unit of copper present the Pickering sprays looked promising. It was accordingly decided to try Pickering sprays containing a higher percentage of copper sulphate the following year.

PICKERING AND BORDEAUX SPRAYS IN 1917.

The arrangement of the plats adopted in 1916 (p. 8) was varied somewhat in 1917, in that the plats were arranged in triplicate and the various plats receiving the same treatment were placed in three different sections of the field.

The copper sulphate content of the Pickering sprays tested varied from 0.3 to 0.7 per cent (Table 2). Rosin-fish-oil soap, 2 pounds to 50 gallons, was added to the Pickering (A) spray applied to plat 12, and dry arsenate of lead, 1 pound to 50 gallons, to the Pickering (A) spray applied to plat 13 and to the Pickering (C) spray applied to plat 14. Each of these three sprays contained 0.5 per cent of cop-

per sulphate. Green Mountain (Norcross strain) potatoes, grown on new land, were sprayed six times during the season, using a Watson sprayer, after the vines were 10 or 12 inches above the ground.

Portions of the two middle rows of each plat were read for blight and used for the yield data. The blight readings (Table 2) are the averages of the last readings of four individuals who worked independently of one another. The results obtained with Bordeaux spray (Pl. I, fig. 1) are more favorable than those secured from using the Pickering spray, with the exception of that applied to plat 1, where they were equally as good (Pl. I, fig. 2). The Pickering sprays which contained less than 0.5 per cent of copper sulphate did not control the blight as effectively as the standard Bordeaux and the Pickering sprays containing 0.6 or 0.7 per cent of copper sulphate.

TABLE 2.—*Effect of various sprays on blight and yield of potatoes (northern Maine, 1917).*[1]

Plat No.	Spray used.	Copper sulphate in spray used.	Late blight.	Yield of tubers.	Rotten tubers.
		Per cent.	*Per cent.*	*Pounds.*	*Per cent.*
1	Pickering (A)	0.7	44	406	12
	Bordeaux, 5–5–50	1.25	45	384	14
	Check		57	347	12
2	Pickering (A)	0.6	52	409	13
	Bordeaux, 5–5–50	1.25	41	414	10
	Check		85	321	10
3	Pickering (C)	0.6	48	404	10
	Bordeaux, 5–5–50	1.25	42	415	11
	Check		95	335	10
4	Pickering (A)	0.5	53	392	12
	Bordeaux, 5–5–50	1.25	42	393	10
	Check		88	301	10
5	Pickering (C)	0.5	53	349	14
	Bordeaux, 5–5–50	1.25	43	325	8
	Check		84	296	12
6	Pickering (A)	0.4	67	355	10
	Bordeaux, 5–5–50	1.25	37	415	11
	Check		96	309	7
7	Pickering (C)	0.4	76	381	11
	Bordeaux, 5–5–50	1.25	39	399	8
	Check		96	320	9
8	Pickering (C)	0.3	63	337	14
	Bordeaux, 5–5–50	1.25	41	451	11
	Check		96	270	9
12	Pickering (A) and rosin-fish-oil soap	0.5	56	345	11
	Bordeaux, 5–5–50	1.25	41	366	17
	Check		96	294	11
13	Pickering (A) and lead arsenate	0.5	56	406	11
	Bordeaux, 5–5–50	1.25	42	430	13
	Check		96	270	9
14	Pickering (C) and lead arsenate	0.5	57	358	10
	Bordeaux, 5–5–50	1.25	44	396	16
	Check		96	294	11

[1] Determinations were made on two rows, each 300 feet long.

The total yield results for plats 1, 2, and 3, treated with Pickering sprays, and for the corresponding Bordeaux-sprayed and check plats are as follows: Pickering, 1,219 pounds; Bordeaux, 1,213 pounds; and check, 1,003 pounds. Plats 4 and 5, to which the Pickering spray having an 0.5 per cent copper sulphate content was applied, yielded 741 pounds of tubers; the corresponding Bordeaux-sprayed plats, 718 pounds; and the check plats, 597 pounds. The plats

treated with Pickering sprays containing less than 0.4 per cent of copper sulphate yielded less than the corresponding Bordeaux-sprayed plats but more than the check plats. The yield of tubers from the sprayed plats showed an increase of from 30 to 40 per cent over that from the unsprayed plats.

A high proportion of rotten tubers was found on all the plats. This was due principally to the wet weather, but partially to the late start made in applying the sprays. The percentage of rotten tubers from the various plats is too variable to permit of any definite conclusions. The tubers from the check plats showed no more rot than those from the sprayed plats. Barrels of potatoes from several of the plats treated with Pickering and Bordeaux sprays, as well as from the check plats, were stored in a potato cellar until February, 1918, when the tubers were sorted. The percentage of rot found among the potatoes from the various plats was very uniform.

In 1917 the blight was severe, and the land used for the experiments was uneven, which gave some of the plats a decided advantage over others. The results showed that a Pickering spray containing 0.7 per cent of copper sulphate is in all respects as efficient as a Bordeaux, 5–5–50, containing 1.25 per cent of copper sulphate. No differences were noted in the relative efficiency of the Pickering (A) and (C) sprays. While these sprays were not shown to be 12 times as effective as standard Bordeaux, the indications were that they were more efficient per unit of copper in the solution used than the Bordeaux mixture.

PICKERING AND BORDEAUX SPRAYS IN 1918.

Series 1.—Tests with Pickering (A) spray, containing 0.7 per cent of copper sulphate, were made on two farms in the vicinity of Presque Isle, as well as on the farm used in 1916 and 1917. Each spray was applied five times to acre plats, using a Watson sprayer, two nozzles per row, in two instances, and a new single-nozzle sprayer in the other. Twice during the season the vines were double sprayed.

The blight, while widespread in July, and threatening to do as much damage as in the previous season, was stopped by the dry weather during August. The blight readings on the vines, made by three individuals working independently, were low, 2 per cent or less, for the Pickering- and Bordeaux-sprayed plats. The check plats showed from 20 to 50 per cent of blight. Evidently, then, the Pickering sprays applied in 1918 checked the blight as effectively as did the Bordeaux mixture.

The yield results on two of the farms varied greatly, according to the location of the plats, because of an uneven distribution of manure and fertilizer over the fields. On the farm previously used for the

FIG. 1.—POTATO VINES SPRAYED WITH BORDEAUX, 3-3-50 (PLAT 55), AND UNSPRAYED (PLAT 54).

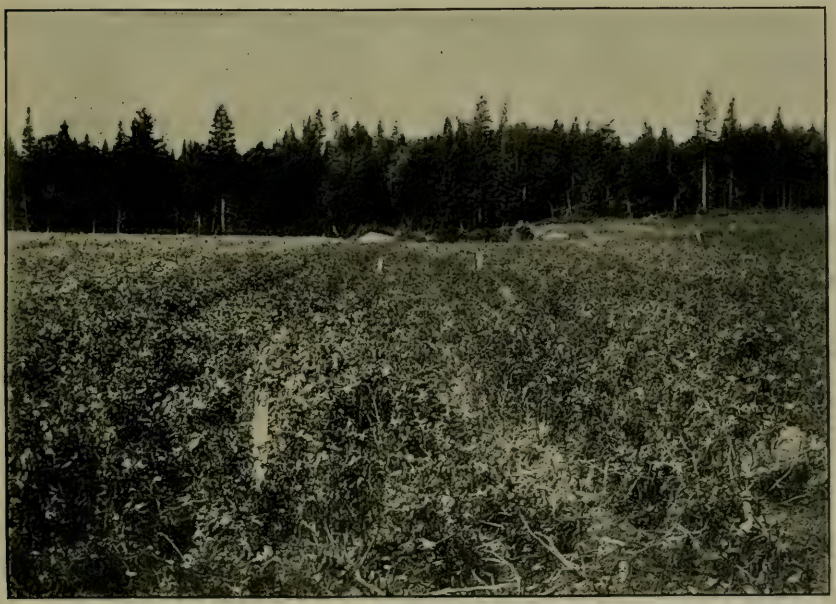

FIG. 2.—POTATO VINES SPRAYED WITH PICKERING SPRAY (LEFT OF STAKE 43) AND UNSPRAYED VINES (RIGHT OF STAKE 43).

FIG. 1.—POTATO VINES SPRAYED WITH BORDEAUX, 5-5-50 (PLAT B), AND WITH PICKERING SPRAY (PLAT I).

FIG. 2.—POTATO VINES SPRAYED WITH BARIUM-WATER SPRAY (PLAT 59) AND UNSPRAYED (PLAT 58).

experimental work, however, where the treatment of the soil was uniform, increased yields were obtained from the plats treated with the Pickering and Bordeaux sprays.

Series 2.—A second series of tests was conducted in northern Maine in 1918, using (1) a Bordeaux spray, (2) Pickering (A) and (C) sprays, (3) a spray in which the limewater was replaced by barium water, and (4) an 0.6 per cent solution of copper sulphate to which powdered arsenate of lead (1 pound to 50 gallons) had been added. In all cases the sprays were made to contain 0.6 per cent of copper sulphate. Green Mountain (Norcross strain) potatoes were first sprayed when the vines were 5 or 6 inches above the ground, after which they received five applications with a Watson sprayer, using two nozzles to a row. The results of this work are recorded in Table 3.

TABLE 3.—*Effect of various sprays on blight and yield of tubers (northern Maine, 1918).*

Plat No.	Spray used.	Copper sulphate in spray used.	Late blight.	Yield of tubers.[1]
		Per cent.	*Per cent.*	*Pounds.*
Farm 1	Pickering (A)	0.7	2.0	274
	Barium water	.7	1.0	277
	Bordeaux, 5–5–50	1.25	1.7	247
	Bordeaux, 4–4–50	1.0	1.0	276
	Bordeaux, 4–2–50	1.0	3.0	258
	Bordeaux, 4–1–50	1.0	2.7	277
Check			20–50	215
Farm 2	Pickering (A)	.7	1.2	261
	Barium water	.7	1.6	264
	Bordeaux, 5–5–50	1.25	1.2	279
	Bordeaux, 4–4–50	1.0	1.5	243
	Bordeaux, 4–2–50	1.0	1.7	198
	Bordeaux, 4–1–50	1.0	1.8	222
Farm 3	Pickering (A)	.7	1.3	227
	Barium water	.7	2.3	303
	Bordeaux, 5–5–50	1.25	2.0	224
	Bordeaux, 4–4–50	1.0	1.3	295
	Bordeaux, 4–2–50	1.0	1.9	370
	Bordeaux, 4–1–50	1.0	2.5	375
Farm 1 (2d series):				
1	Bordeaux, 5–5–50	1.25	.5	244
2 (check)			33.0	235
3	Pickering (A)	.60	1.7	241
4	Pickering (C)	.60	1.3	251
5	Bordeaux, 2½–2½–50	.60	3.0	248
6	Barium water	.60	1.7	241
7	Copper sulphate and lead arsenate	.60	1.8	237
8	Bordeaux, 5–5–50	1.25	1.2	242
9 (check)[2]			45.0	175

[1] Determinations made on two rows, each 150 feet long.

[2] Plat partially shaded.

The blight readings of all the plats sprayed were practically the same (1 to 3 per cent), while the vines on the check plats showed 33 and 45 per cent infection. The yields were remarkably uniform for all the plats, with the exception of the last check plat, which was shaded by the adjacent trees. The dry season and the fact that the vines were killed by frost on September 9 tended to reduce the increased yields which are usually obtained from sprayed plats. Here the Pickering sprays containing 0.6 per cent of copper sulphate

gave as good results as the Bordeaux sprays containing 1.25 per cent of copper sulphate. In fact, all of the sprays gave practically the same results. The only plats giving yields below 240 pounds were the two check plats and the one treated with copper sulphate and lead arsenate. The yield and blight readings were practically the same for the plats sprayed with the Pickering solution as for those sprayed with Bordeaux mixture (Plate II, fig. 1).

In Central Maine.—Separate plats of about ½ acre each of Green Mountain and Rural New Yorker seed potatoes, in Foxcroft, Me., were treated with Pickering and barium-water sprays of 0.7 per cent copper sulphate content, and with reduced lime Bordeaux, 4–4–50, 4–2–50, and 4–1–50, sprays. The rest of the 8-acre field was sprayed with a standard Bordeaux, 5–5–50. Plats sprayed with standard Bordeaux were placed between the experimental plats. A spray wagon treating six rows at a time was used. As the vines were not sprayed until July 15, they were double sprayed at each spraying, or four times altogether. The results of these tests are given in Table 4.

TABLE 4.—*Effect of various sprays on late blight and yield of potatoes (Central Maine, 1918).*

Plat No.	Spray used.	Copper sulphate in spray.	Green Mountain.		Rural New Yorker.	
			Blight on vines.	Yield.[1]	Blight on vines.	Yield.[1]
		Per cent.	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*
1	Pickering (A)	0.7	Trace.	331	Trace.	324
2	Barium water	.7	...do.....	322	...do.....	332
[2]3	Bordeaux, 4–4–50	1.0	...do.....	285	...do.....	285
4	Bordeaux, 4–2–50	1.0	...do.....	338	...do.....	333
5	Bordeaux, 4–1–50	1.0	...do.....	381	...do.....	319
6	Bordeaux, 5–5–50	1.25	...do.....	258	...do.....	330

[1] Obtained from two rows, 150 feet long. [2] A ledge of rock in this plat.

On the whole, the blight results were uniform and very low. Early in August a trace of blight appeared through this and other fields, but the dry August practically put an end to it. The yields of Green Mountain tubers varied somewhat, particularly at the lower end of the field where plats 5 and 6 were located, but plats 1, 2, and 4 gave practically the same yields. The Rural New Yorker potatoes were grown on a more uniform portion of the field, so that they showed uniform results, except in plat 3, where a ledge of rock reduced the yield. Only traces of blight were seen on the Rural New Yorker vines, which are much more rangy and stand up from the ground higher than the Green Mountain vines, making them less liable to infections of late blight.

BARIUM-WATER SPRAYS IN 1916.

It was thought that the greater solubility of barium hydrate over lime might be an advantage in the preparation of a spray like the

Pickering sprays. While barium hydrate costs much more than lime, barium, unlike lime, is dissolved, leaving no residue. Barium is said to possess some fungicidal powers which lime does not. Osterhout (16) noticed a peculiar contraction of certain species of spyrogyra in 0.0001 molecular solution of barium chlorid, which was not produced by chlorid of lime or other salts.

A spray containing 0.38 per cent of copper sulphate was prepared by dissolving barium hydrate in water and adding the copper sulphate solution to the barium water. When necessary more barium water was added until no free copper was present, as determined by tests with potassium ferrocyanide.

In 1916 this spray was applied four times, while the regular 5–5–50 Bordeaux was applied five times. The plats sprayed with barium water were next to the check plats and the Bordeaux-sprayed plats were between two sprayed plats. The blight readings were: Barium-water-sprayed plats, 25 and 12 per cent; Bordeaux-sprayed plats, 12 and 10 per cent; check plats, 75 and 41 per cent. The yields of tubers were: Barium-water-sprayed plats, 1,142 and 1,052 pounds; Bordeaux-sprayed plats, 1,125 and 1,168 pounds; check plats, 1,058 and 1,138 pounds. In view of the fact that only 0.38 per cent of copper sulphate was present in the spray and but four applications were made, while the Bordeaux was applied five times, these results were sufficiently satisfactory to warrant additional tests.

BARIUM-WATER SPRAYS IN 1917.

In 1917 a barium-water spray made to contain 0.7 per cent of copper sulphate was tested. The average percentage of late blight on the vines was: Check plat, 76 per cent; barium-water-sprayed plat, 21 per cent; Bordeaux-sprayed plat, 13 per cent. The yield of tubers and percentage of rot from the two middle rows of each plat, each row being 100 feet long, were: Standard Bordeaux-sprayed plat, 148 pounds, 8 per cent rot; barium-water-sprayed plat, 168 pounds, 5 per cent rot; check plat, 130 pounds, 6 per cent rot. The barium-water-sprayed plat adjoined a check plat, while the Bordeaux-sprayed plat had sprayed plats on either side.

BARIUM-WATER SPRAYS IN 1918.

In 1918 a barium-water spray containing 0.7 per cent of copper sulphate, which had given excellent results in 1917, was tested on acre plats in a commercial way, and another barium-water spray, containing 0.6 per cent of copper sulphate, was tested on a smaller scale.

The plats to which 0.7 per cent barium-water spray was applied on the commercial scale gave blight yield readings of from 1 to 2.3 per cent as compared with readings of from 1.2 to 2.0 per cent in the

case of those sprayed with standard Bordeaux and of from 20 to 50 per cent in the case of the unsprayed plats. The barium-water-sprayed plats yielded from 264 to 303 pounds of tubers, the Bordeaux-sprayed plats from 247 to 313 pounds, and the check plats 215 pounds.

The application of the 0.6 per cent barium-sulphate spray to smaller plats gave an average blight reading of 1.7 per cent, as compared with 0.5 and 1.2 per cent for the Bordeaux, 5–5–50, mixture, and 33 and 45 per cent when no spray was used. The yields of tubers from two rows, each 150 feet long, were: Bordeaux-sprayed plat, 244 pounds; check plat, 235 pounds; barium-water-sprayed plat, 241 pounds.

These results, extending over three seasons, particularly those of 1917 and 1918, indicate that a spray made with barium hydrate and containing 0.7 per cent of copper sulphate gives a satisfactory control of blight and the same yield of tubers as a Bordeaux, 5–5–50, containing 1.25 per cent of copper sulphate. Plate II, figure 2, shows the protective action given by the barium-water spray in 1918, when the blight was severe.

In preparing the barium-water spray containing 0.7 per cent of copper sulphate, equal parts of copper sulphate and barium hydrate (2.8 pounds of barium hydrate and 2.8 pounds of copper sulphate to 50 gallons) were found to be satisfactory. While such a spray gave good results and reduced the copper sulphate used 44 per cent, the price of barium hydrate is so high that such a spray can not be considered commercially practicable at the present time. If the price of barium hydrate drops, or if barium chlorid, which sells for $75 per ton, can be used, an effective spray may be cheaply prepared. The fact that no residue is left, that the barium hydrate may be added to the spray tank with the water and dissolved there, and that there is reduced wear and tear on apparatus, may induce a trial of this spray, particularly if the yields are shown to be stimulated to a greater extent than with Bordeaux, 5–5–50.

REDUCED MILK-OF-LIME SPRAYS IN 1917.

Bordeaux, 3–3–50 and 3–1½–50, sprays were applied to potatoes during the season of 1917. The reason for reducing the proportion of lime used as milk of lime was to determine its influence on the fungicidal power of the copper and its effect upon the adhesive properties of the spray.

Blight control.—Check plat, 71 per cent; plat sprayed with Bordeaux, 5–5–50, 13 per cent; plat sprayed with Bordeaux, 3–3–50, 38 per cent; and plat sprayed with Bordeaux, 3–1½–50, 26 per cent.

Yield.—Check plat, 139 pounds; plat sprayed with Bordeaux, 5–5–50, 158 pounds; plat sprayed with Bordeaux, 3–3–50, 148 pounds; plat sprayed with Bordeaux, 3–1½–50, 172 pounds.

Rotten tubers.—Check plat, 3 per cent; plat sprayed with Bordeaux, 5–5–50, 4 per cent; plat sprayed with Bordeaux, 3–3–50, 8 per cent; plat sprayed with Bordeaux, 3–1½–50, 8 per cent.

The Bordeaux, 5–5–50, spray gave the lowest average readings for blight. The largest yield of tubers came from the plat sprayed with Bordeaux, 3–1½–50. Apparently the percentage of rotten tubers was not influenced by the spray used. The fact that the plats sprayed with Bordeaux, 3–3–50 and 3–1½–50, were on lower ground than the other two plats, together with the wetness of the season, accounted for the high percentage of rotten tubers found on them.

REDUCED MILK-OF-LIME SPRAYS IN 1918.

In 1918 one-acre plats were sprayed with Bordeaux, 4–4–50, 4–2–50, and 4–1–50, to determine the influence of varying amounts of lime on a definite amount of copper. The average results of these tests, which were conducted on the same fields as the Pickering and barium-water tests, appear in Table 3.

The blight readings are so low that it is impossible to draw a definite conclusion from them. Those for the plats sprayed with Bordeaux, 5–5–50 and 4–4–50, are lower than those for the plats sprayed with Bordeaux, 4–2–50 and 4–1–50. While the Bordeaux, 4–1–50, gave somewhat larger yields than the other sprays, the average yields of tubers were practically the same for all the sprayed plats. The slight variation which exists is undoubtedly due to the location of the plats and the fertilizer used rather than to the sprays.

Adherence of Copper from Sprays to Leaves.

The power of various sprays to adhere to potato leaves was tested by Girard (11), who employed standard Bordeaux, Bordeaux made with half the usual amount of lime, Bordeaux made with aluminum sulphate, copper and soda mixture, and copper and acetate of lime mixture. The sprayed plats were subjected to artificial rain for various periods. The Bordeaux spray made with half the usual amount of lime left the largest amount of copper on the leaves. The addition of sulphate of aluminum was of no value. Butler (7) also concludes that a Bordeaux mixture made with a medium amount of lime has greater adhesive properties than one to which the full amount of lime has been added, and considers the alkaline Bordeaux sprays more adhesive than the acid or neutral Bordeaux sprays.

Method of estimating copper on leaves.—To determine how much of the copper from the various sprays actually remained on the potato leaves, sets of 50 leaves were picked from the vines on the different plats, the leaves from each plat being placed in separate envelopes. Directly after picking tracings were made of the outlines of the leaves and were later measured with a planimeter to obtain the areas of

the leaves. The area of one side of the leaves only was used in making the calculations. The leaves were dried and used for analysis for copper. The results were expressed as milligrams of copper per square millimeter of leaf surface. By weighing the leaves when dry it was then possible to express the results both as parts of copper per million on the dried leaves and as milligrams of copper per square meter of leaf surface.

Method of determining copper on leaves.—The leaves were placed in 4½-inch porcelain dishes and ashed in the muffle at dull red heat. The ash was covered with 30 cc. of 1-3 nitric acid and allowed to stand over night. It was then filtered and washed, the filtrate made faintly ammoniacal, and brought to a boil. Next it was cooled, made to suitable volume, and filtered. An adequate aliquot was taken for the colorimetric estimation of the copper. This aliquot, as well as solutions of standard copper sulphate, containing added ammonia and nitric acid, were evaporated to dryness in clean, white, 3-inch porcelain dishes. To the residues 5 cc. of distilled water and 3 drops of acetic acid were added, and finally 3 drops of 10 per cent potassium ferrocyanid, the dishes being rotated to mix the solutions, which were immediately compared with the standards. The results are expressed as parts of copper per million. This method has been checked against the electrolytic copper method and found to give good results. The standard copper sulphate solution was made to contain 0.0001 gram of copper per cc.

IN 1916.

On August 12, two days after the third spray had been applied, a set of leaves (lot 1) was taken from the vines on the sprayed plats. On August 24, seven days after the leaves had been sprayed, additional samples of leaves (lot 2) were taken. The results of the analyses, which were made in duplicate, are given in Table 5. Average results for four sets of leaves, or 200 leaves, from each plat show that the barium-water and three of the seven Pickering sprays employed left a higher percentage of copper on the leaves to 0.1 per cent of copper sulphate present in the spray than Bordeaux, 5–5–50. The other four Pickering sprays did not show as high a ratio of copper on the leaves as did the Bordeaux, 5–5–50. It must be remembered, of course, that the Pickering sprays were applied four times, while the Bordeaux spray was applied five times. Although the Bordeaux-sprayed leaves always showed the presence of more copper than any of the others, it is apparent that, considering the amount of copper sulphate used, the copper of the Pickering sprays adhered equally as well. The leaves from the vines treated with Pickering (A) spray and rosin-fish-oil soap showed the presence of more copper than did those from the vines sprayed with plain Pickering (A) spray containing 0.38 per cent of copper sulphate. The amounts of copper on the leaves of the vines

sprayed with Pickering (A) and (C) sprays varied markedly. On an average more copper was found on the leaves sprayed with Pickering (C) sprays than on those treated with Pickering (A) sprays.

TABLE 5.—*Adherence of copper from various sprays to potato leaves (northern Maine).*

Plat No.	Spray.	Copper sulphate in spray.	Copper adhering to leaves.							
			Parts per million (dry basis).		Parts per million per 0.1 per cent $CuSO_4$ in spray (dry basis).		Mg. per square meter of leaf surface.		Mg. per square meter of leaf surface per 0.1 per cent $CuSO_4$ in spray.	
			Lot 1.[1]	Lot 2.[2]	Lot 1.[1]	Lot 2.[2]	Lot 1.[1]	Lot 2.[2]	Lot 1.[1]	Lot 2.[2]
1916.		*Per cent.*								
.....	Standard Bordeaux, 5-5-50	1.25	163.3	332.6	13.0	26.6	31.15	.....	2.5	.....
.....	Pickering (A)	.64	149.7	53.7	23.4	8.4	15.77	.....	2.4	.....
.....	.....do	.38	29.4	22.3	7.7	5.9	8.00	.....	2.1	.....
.....	.....do	.13	35.8	19.6	27.6	15.1	11.64	.....	9.0	.....
.....	.....do	.065	9.11	7.2	14.0	11.1	.80	.....	1.2	.....
.....	Pickering (C)	.23	42.9	23.8	18.7	10.3	7.97	.....	3.5	.....
.....	.....do	.115	36.6	18.9	31.8	16.4	5.99	.....	5.2	.....
.....	.....do	.36	61.8	97.9	17.2	27.2	12.80	.....	3.6	.....
.....	Pickering (A) and rosin-fish-oil soap	.38	120.8	54.0	31.8	14.0	24.13	.....	6.4	.....
.....	Barium water	.38	73.6	38.0	19.4	10.0	5.98	.....	1.6	.....
1917.										
1.....	Pickering (A)	.7	519.8	571.7	74.2	81.7	11.17	18.61	1.60	2.66
2.....	.....do	.6	455.1	533.9	75.8	89.0	10.64	13.07	1.77	2.18
3.....	Pickering (C)	.6	422.6	373.6	70.4	62.3	10.96	10.39	1.83	1.73
4.....	Pickering (A)	.5	338.1	431.5	69.6	86.3	6.98	14.13	1.40	1.83
5.....	.....do	.5	277.5	334.5	55.5	66.9	5.34	8.96	1.07	1.80
6.....	.....do	.4	274.2	319.3	68.6	79.8	6.25	9.10	1.56	1.82
7.....	Pickering (C)	.4	111.9	200.5	28.0	50.1	2.11	7.00	.53	1.78
8.....	.....do	.3	138.6	163.3	46.2	54.4	3.32	3.97	1.11	1.32
12.....	Pickering (A) and rosin-fish-oil soap	.5	141.4	338.0	28.3	67.6	2.96	9.24	.59	1.85
13.....	Pickering (A) and lead arsenate	.5	128.9	275.0	25.8	55.0	2.66	8.57	.53	1.71
14.....	Pickering (C) and lead arsenate	.5	213.3	390.0	42.7	78.0	4.38	10.02	.88	2.00
.....	Bordeaux, 5-5-50	1.25	387.4	1,073.7	31.0	86.0	7.55	30.00	.60	2.40
Check.	.....	.....	.....	41.8	.....	.....	.....	.....	.....	.....
Check.	.....	.....	.....	22.05	.....	.....	.....	.....	.....	.....
.....	Bordeaux, 3-3-50	.75	363.0	956.19	48.4	127.5	5.87	31.71	.78	4.23
.....	Bordeaux, 5-5-50	1.25	566.4	1,641.60	45.3	131.3	22.12	48.74	1.77	3.90
.....	Bordeaux, 3-1½-50	.75	618.1	1,098.0	82.4	146.4	11.41	31.44	1.52	4.19
Check.	.....	.....	.....	16.9	.....	.....	.....	.....	.....	.....
.....	Barium water	.7	271.4	878.3	38.8	125.5	5.86	21.37	.84	3.05
.....	Burgundy mixture	1.25	.....	1,217.5	.....	97.4	.....	36.19	.....	2.89
.....	Bordeaux, 5-5-50	1.25	.....	1,703.0	.....	136.4	.....	51.57	.....	4.13
1918.										
1.....	Pickering (A)	.7	1,650	1,700	236	243	.....	.....	.....	.....
2.....	Barium water	.7	1,400	1,100	200	157	.....	.....	.....	.....
3.....	Bordeaux, 4-4-50	1.0	1,950	1,700	195	170	.....	.....	.....	.....
4.....	Bordeaux, 4-2-50	1.0	1,850	1,500	185	120	.....	.....	.....	.....
5.....	Bordeaux, 4-1-50	1.0	1,400	1,200	140	184	.....	.....	.....	.....
6.....	Bordeaux, 5-5-50	1.25	2,250	2,300	180	.....	.....	.....	.....	.....
A.....	Pickering (A)	.6	1,300	.....	217	.....	.....	.....	.....	.....
C.....	Pickering (C)	.6	1,400	.....	233	.....	.....	.....	.....	.....
D.....	Bordeaux	.6	1,400	.....	233	.....	.....	.....	.....	.....
E.....	Barium water	.6	1,200	.....	200	.....	.....	.....	.....	.....
F.....	Copper sulphate and lead arsenate	.6	900	.....	150	.....	.....	.....	.....	.....

[1] In 1916, picked two days after spraying, and in 1917, eight days after spraying.
[2] In 1916, picked seven days after spraying, and in 1917, two days after spraying.

IN 1917.

Leaves picked on August 11, eight days after spraying (lot 1) and on August 24, two days after spraying (lot 2), were analyzed with the results shown in Table 5.

Lot 1.—The copper of the Pickering sprays adhered to the leaves in proportionally greater amounts than that of the Bordeaux spray. Per unit of copper sulphate in the spray more copper was deposited on the leaves sprayed with the three Pickering sprays which contained the highest percentages of copper sulphate than on those sprayed with Bordeaux, but less on the leaves treated with the other Pickering sprays. The results for copper on the leaves sprayed with barium water were low. Of the leaves treated with the 3–3–50 and 3–1½–50 sprays those receiving the 3–1½–50 spray showed the largest deposits.

Lot 2.—As a rule, more copper adhered to the leaves sprayed with Bordeaux than to those to which any of the other sprays were applied. In several instances, however, the results for the Pickering-sprayed leaves were equal to those for the Bordeaux-sprayed leaves per unit of copper sulphate in the spray. The addition of lead arsenate or rosin-fish-oil soap to the Pickering sprays did not increase the amount of copper which adhered to the leaves. More copper adhered to the leaves sprayed with standard Bordeaux than to those sprayed with barium water or Burgundy mixture.

Average results.—More of the copper of the Pickering (A) than of the Pickering (C) sprays adhered to the leaves. In three of the eight Pickering sprays tested, the copper adhered to the leaves in a higher proportion per copper sulphate content of the spray than the copper of the standard Bordeaux, 5–5–50. The Bordeaux, 3–1½–50, spray gave higher results than either the Burgundy mixture or barium water. In proportion to the amount of copper sulphate present in the spray, the Burgundy mixture gave the lowest results of all.

IN 1918.

During the season of 1918, the adherence of copper to potato leaves was determined for Pickering (A) spray, containing 0.7 per cent of copper sulphate, for barium-water spray, with the same copper sulphate content, and for Bordeaux, 4–4–50, 4–2–50, and 4–1–50, sprays, each containing 1 per cent of copper sulphate. The results (Table 5) are very uniform except those for the Bordeaux, 4–1–50, spray, used on plat 5, which gave lower figures than the sprays used on plats 1, 2, 3, 4, and 6. The highest average figure for copper per unit of copper sulphate in the spray was obtained in the case of the Pickering (A) spray with a copper sulphate content of 0.7 per cent, applied to plat 1. In the tests on plats A, C, D, E, and F, in which sprays containing 0.6 per cent of copper sulphate were employed, the amount of copper adhering on the leaves treated with Pickering (C) spray was the same as the amount adhering to those sprayed with Bordeaux. The leaves sprayed with Pickering (A) spray gave slightly lower results and those treated with the barium-water spray,

still lower ones. The solution of copper sulphate and lead arsenate did not seem to adhere to the leaves as well as the other sprays.

SUMMARY.

The various Pickering and Bordeaux sprays tested adhered equally well to the potato leaves. Little difference was noted between the adhesive property of the copper from the Pickering (A) and that of the copper from the Pickering (C) solutions. The 1916 results favored the Pickering (C) spray, while the 1917 results were higher in the case of Pickering (A) sprays. The addition of either rosin-fish-oil soap or lead arsenate to a Pickering spray failed to increase its adhesive properties. In 1916 the results on leaves sprayed with barium-water spray were higher than, in 1917 lower than, and in 1918 equal to the standard Bordeaux results. A reduction in the amount of milk of lime used in preparing a standard Bordeaux type of spray did not appear to influence the adhesive properties of the spray until the amount used was less than that necessary to combine with the copper present, when a decrease in adhesive power resulted. The copper of the Burgundy mixture (sal-soda Bordeaux) did not adhere as well as the copper of standard Bordeaux, for the reason that all of the copper had not been precipitated by the sal soda.

INJURY TO VINES AND TUBERS.

No injury to vines or tubers was observed as the result of the application of any of the sprays used in these tests.

SUMMARY.

PICKERING SPRAYS.

A Pickering spray containing 0.7 per cent of copper sulphate controlled the late blight as well as, and gave yield results equal to those obtained with, Bordeaux, 5–5–50, containing 1.25 per cent of copper sulphate. The copper in the Pickering sprays was apparently twice as effective as that in standard Bordeaux, 5–5–50. Pickering sprays containing 0.6 per cent of copper sulphate gave the same yield of tubers and nearly as effective control of late blight as Bordeaux, 5–5–50. Pickering sprays containing less than 0.6 per cent of copper sulphate did not give satisfactory control of late blight. The claims of Bedford and Pickering (3, 4) that the copper of the limewater sprays is from 10 to 12 times as effective as the copper of standard Bordeaux were not substantiated by the results of these experiments. Pickering (A) and (C) sprays were found to be equally effective in controlling late blight on potatoes.

The Pickering sprays adhered to the leaves as well as standard Bordeaux. The use of rosin-fish-oil soap or lead arsenate with Pick-

ering sprays did not materially influence their adhesive properties on potato leaves. No injury to the leaves or to the potato plants was caused by any of the Pickering sprays tested.

The amount of copper sulphate essential for the control of late blight on potatoes in Maine may be reduced 44 per cent by the use of Pickering sprays. The amount of lime required is reduced also and all grit removed from the spray, while at the same time the wear and tear on spray machinery is greatly diminished. These results were obtained in Maine where the principal potato trouble is late blight. It is impossible to state what the efficacy of Pickering sprays on potatoes would be in sections where other troubles predominate.

BARIUM-WATER SPRAYS.

Tests with a barium-water spray containing 0.7 per cent of copper sulphate showed that it gave practically the same control of late blight and the same yields as Bordeaux, 5–5–50. In fact, in 1917 and 1918 the yields were slightly larger on plats sprayed with barium water than on those sprayed with Bordeaux.

REDUCED-MILK-OF-LIME SPRAYS.

The 3–1½–50 spray tried in 1917 (a severe blight year) gave a larger yield and a lower blight reading than the 3–3–50 spray. In 1918, the blight readings for the plats where the 4–1–50 spray was employed were a little higher than for those where the 4–4–50 spray was used. Apparently the amount of lime present in a Bordeaux spray used for potatoes in Maine has little effect on the fungicidal power. As long as sufficient lime is present to combine with the copper, the extra lime has no fungicidal advantage, but has several disadvantages.

Less copper adhered to the leaves when a 4–1–50 spray was employed than when 4–4–50 and 4–2–50 sprays were used. This may be explained by the presence of free copper sulphate in the 4–1–50 sprays.

STANDARD BORDEAUX SPRAYS.

In sections where the blight may be severe, such as northern Maine, a Bordeaux, 5–5–50, is recommended. In other States where the blight is usually less severe a Bordeaux, 4–4–50, is desirable.

GRAPES.

Control of Fungous Diseases.

IN NEW JERSEY.

Four acres of Concord grapes near Vineland, N. J., were treated with Pickering (A) and (C) sprays, varying in copper sulphate content from 0.065 to 0.64 per cent, and with a standard Bordeaux,

3–3–50, spray, containing 0.75 per cent of copper sulphate. A Pickering (A) spray containing 0.38 per cent of copper sulphate was used alone and in combination with rosin-fish-oil soap. One plat was held unsprayed as a check plat. The sprays were applied on May 18, May 27, June 15, and July 7, 1916. A power sprayer was used for each spraying with the Bordeaux and for the May sprayings with the Pickering spray, while a hand-pump sprayer was employed for the June and July applications of the Pickering spray. Because of injury to the vines sprayed with the strongest Pickering solutions after a severe hail storm occurring on June 11, no further applications of these sprays were made. The spraying of one or two rows of grapes with the weaker Pickering sprays was, however, continued throughout the season.

TABLE 6.—*Effect of various sprays on blight and yield of grapes (New Jersey).*

Plat No.	Spray used.	Copper sulphate in spray.	Condition of fruit when picked.				Net weight of grapes picked from two rows.	Spray injury noted June 13.
			Sound.	Black rot.	Downy mildew.	Total diseased.		
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	
1	Pickering (A)	0.64	(1)	(1)	(1)	(1)	121	Leaves and fruit greatly injured; many buds destroyed.
2	do	.38	(1)	(1)	(1)	(1)	411	Almost complete defoliation: part of fruit destroyed.
2	Pickering (A) and rosin-fish-oil soap.	.38	(1)	(1)	(1)	(1)	784	Do.
3	Pickering (A)[2]	.13	76.12	21.17	2.71	23.88	.....	Leaves noticeably injured.
3	do.[3]	.13	71.68	25.00	3.33	28.33	961	Do.
4	do	.965	69.63	25.98	4.39	30.37	1,501	Leaves slightly injured.
5	Pickering (C)[2]	.23	(1)	(1)	(1)	(1)	.....	Large proportion of leaves destroyed.
5	do[3]	.23	(1)	(1)	(1)	(1)	949	Do.
6	do	.115	85.09	12.43	1.48	14.01	1,502	Leaves slightly injured.
7	do	.36	(1)	(1)	(1)	(1)	892	Large proportion of leaves destroyed.
.....	Bordeaux, 3–3–50	.75	92.91	6.79	.29	7.02	1,375	Leaves slightly injured.
Check		.....	.00	70.64	37.53	100.00	830	

[1] Fungus control satisfactory.
[2] Spray applied three times.
[3] Spray applied to first two rows four times.

The results for the control of fungous diseases in New Jersey (Table 6) indicate that the control of disease was in direct proportion to the spray injury of the vines. Apparently the strongest Pickering spray, which contained 0.64 per cent of copper sulphate (plat 1), controlled the fungous diseases more effectively than the Bordeaux sprays, showing the high availability of the copper of the Pickering sprays. The injury, however, was so severe that the spray could not be used commercially.

IN VIRGINIA.

Two acres of grapes, largely Concords, in poor condition, in Vienna, Va., were sprayed with Pickering sprays and with a standard Bor-

deaux, 3–3–50, spray. The Pickering spray was used alone and in combination with rosin-fish-oil soap. The sprays were applied four times, May 15–16, May 25–26, June 12–13, and July 1–3, 1916, with a barrel pump sprayer.

Early in July many spots of black rot were seen on the leaves of the check plat, but none on the leaves of the sprayed plats. On June 26 some black-rot spots were observed on the leaves from all plats except those sprayed with Bordeaux, 3–3–50, and Pickering (A) containing 0.64 per cent of copper sulphate (plats A and 1). Plat 7, sprayed with Pickering (C) containing 0.36 per cent of copper sulphate, showed very few spots. The check plat showed the largest number of infected leaves. One row of vines in plat 1 did not receive the second application. These vines showed neither the spray injury nor the control of rot apparent in the rest of the vines of plat 1.

TABLE 7.—*Effect of various sprays on black rot of grape leaves (Virginia).*

Plat No.	Spray used.	Copper sulphate in spray.	Amount of black-rot leaf spot.	Remarks.
		Per cent.	*Per cent.*	
A	Bordeaux, 3–3–50	0.75	3.5	Condition of vines good; slightly injured.
1	Pickering (A)	.64	3.5	Leaves and fruit badly injured.
2	do	.38	5.0	Leaves severely injured; fruit somewhat.
2b	Pickering (A) and rosin-fish-oil soap.	.38	5.0	Do.
3	Pickering (A)	.13	11.0	Slight burning of leaves.
5	Pickering (C)	.23	6.5	Do.
7	do	.36	5.0	Leaves severely injured; fruit somewhat.
Check		.00	100.0	Vines not much injured.

The results in Table 7 show that the four strongest Pickering sprays tested (plats 1, 2, 2b, and 7) and the standard Bordeaux spray gave an excellent control of black-rot leaf spot on the leaves. The sprays used on plats 3 and 5 gave a less effective control of the disease. Black-rot spots were seen on the leaves of all the vines on the check plat. The weeds in the vineyard were high, and the weather was moist, rendering conditions for infection excellent. Of all the experimental plats, No. 5 looked the best, although not as well as the plat sprayed with standard Bordeaux.

YIELD.

IN NEW JERSEY.

The yield of grapes sprayed varied with the injury to the vines, which in turn depended upon the percentage of copper sulphate in the Pickering sprays employed. The two weakest (those used on plats 4 and 6) gave good yield results, but plat 4 showed only 69 and plat 6 only 85 per cent of sound berries, as compared with 93 per cent obtained from the plat sprayed with Bordeaux, 3–3–50.

IN VIRGINIA.

It was considered impracticable to attempt to determine the weight of grapes from the different plats in Virginia. From the three rows sprayed with Bordeaux 26 crates of grapes were obtained, an average of $8\frac{2}{3}$ crates per row. From the 20 rows of grapevines sprayed with the Pickering sprays 26 crates of salable grapes were secured, an average of 1.3 crates per row. No grapes were harvested from the unsprayed check rows. Not all of the grapes from the plats sprayed with Pickering spray were picked, as some of the fruit was small and immature.

Adherence of Copper From Various Sprays to Leaves.

IN NEW JERSEY.

Duplicate samples of leaves from the plats treated with the various sprays were gathered on June 6 (10 days after the second spraying) and on June 8 (12 days after the second spraying). Forty leaves from each set were analyzed, the results obtained on those gathered on June 6 being shown in Table 8. The area of one side only of the leaves was considered in calculating the area figures. The outlines of the fresh leaves were traced on paper, and the tracings later measured by a polar planimeter (p. 17).

Table 8.—*Adherence of copper from various sprays to grape leaves.*

Plat No.	Spray used.	Copper sulphate in spray used.	Copper adhering to leaves.			
			Parts per million (dry basis).	Parts per million, per 0.1 per cent $CuSO_4$ in spray.	Mg. per square meter of leaf surface.	Mg. per square meter of leaf surface per 0.1 per cent $CuSO_4$ in spray.
New Jersey:		*Per cent.*				
B	Bordeaux, 3–3–50	0.75	1,459	194	64.0	8.5
1	Pickering (A)	.64	982	153	46.2	7.2
2	do	.38	750	197	29.9	7.8
2a	Pickering (A) and rosin-fish-oil soap	.38	709	187	27.8	7.3
3	Pickering (A)	.13	383	295	14.1	10.8
4	do	.065	110	170	.4	.6
5	Pickering (C)	.23	110	48	4.2	1.8
6	do	.115	184	160	6.2	5.4
7	do	.36	285	80	10.5	3.0
Check			11		.4	
Virginia:						
A	Bordeaux, 3–3–50	0.75	1,440	192	44.6	6.0
1	Pickering (A)	.64	191	30	6.9	1.1
2	do	.38	18	5	.7	.2
2b	Pickering (A) and rosin-fish-oil soap	.38	392	103	16.1	4.2
3	Pickering (A)	.13	[1]			
5	Pickering (C)	.23	174	76	5.6	2.4
7	do	.36	321	89	12.8	3.6
Check						

[1] Trace.

The area results show more decisively than do the weight results that the copper from the Pickering (A) sprays adhered to the leaves in proportionately greater amounts than did that from the Pickering

(C) sprays. The leaves sprayed with Bordeaux mixture contained more copper and a higher ratio of copper per unit of copper sulphate present in the spray than the average for those treated with the Pickering sprays, showing that the copper of the Pickering sprays did not adhere to the grape leaves as well as that of the standard Bordeaux spray. The addition of rosin-fish-oil soap to the Pickering (A) spray used on plat 2 did not increase the adherence of copper to the leaves.

IN VIRGINIA.

Duplicate sets of leaves from the plats treated with the different sprays were gathered on June 1 (six days after the second spraying) and on June 3 (eight days after the second spraying) and analyzed (Table 8).

The results, both by weight and area, for the leaves gathered June 1 show that the copper of the Bordeaux spray adhered practically twice as well as that from the Pickering sprays. The use of rosin-fish-oil soap seemed to be of decided advantage. These results do not agree with those obtained by analyzing leaves in New Jersey where similar sprays were used. The low results for copper on the Pickering-sprayed leaves in Virginia, as compared with those obtained on leaves treated with sprays of the same formula and strength in New Jersey, may be accounted for in part by the fact that in New Jersey the first two applications were made with a power sprayer.

Injury to Vines.

IN NEW JERSEY.

Until the severe hail storm of June 11 no burning or other injury was noticed on the Pickering-sprayed plats. After the storm, however, the leaves were torn, the grapes were punctured, and young shoots broken from the vines. The Pickering-sprayed plats were then reduced in size, only one or two rows of the vines treated with the weaker Pickering sprays being continued through the rest of the season. The stronger Pickering sprays were dropped entirely. By July 7 new foliage had appeared on all the vines and no additional injury was evident.

Copper sprays used on grapes are often mixed with lead arsenate. Lead arsenate, however, was not used with the Pickering or Bordeaux sprays in this investigation. Consequently its influence on the burning of the foliage was not determined.

The Pickering sprays containing 0.23 per cent and more of copper sulphate controlled the fungous diseases as well as the Bordeaux spray. As commercial sprays, however, they are impracticable because of their tendency to injure the grape leaves and fruit. The use of rosin-fish-oil soap with Pickering (A) containing 0.38 per cent of copper did not affect the caustic properties of the spray.

IN VIRGINIA.

On June 10 a heavy hail storm broke the leaves, punctured the grapes, and broke off many shoots from the vines. Two or three days after the storm serious burning of the leaves was noticed. This injury was particularly severe on the plats sprayed with the strongest Pickering solutions. The weakest Pickering spray produced about the same injury as the Bordeaux spray. On June 26 new growth appeared on all the sprayed vines, and a fourth spraying was made on July 3, with no additional spray injury. As in the case of the tests in New Jersey, the injury to the leaves was in direct proportion to the percentage of copper sulphate present in the Pickering sprays.

Among the numerous theories advanced to explain the burning or scorching of foliage by copper sprays are the following: (1) A specific susceptibility of the protoplasm of the plant to copper; (2) solvent properties or activities of the cell sap of the plant on the copper compound of the spray; (3) permeability of the epidermis or cuticle to the cell contents when conditions are favorable for exosmosis and for a trace of copper which has been rendered soluble; (4) weather conditions following spraying, particularly moisture, which provides suitable conditions for the exosmosis of some of the contents of the cells of leaves; (5) the amount of spray on the leaves or foliage, the proportions of other constituents, such as lime, to the copper in the spray, the condition of the leaves, whether normal or injured by the weather, insects, etc., and, above all, the climate.

Effect on Maturing of Fruit.

IN VIRGINIA.

At the time of picking, samples of grapes from the different plats were analyzed for reducing sugar, sucrose, and acidity, using the methods of the Association of Official Agricultural Chemists, in order to determine the influence of the sprays in preventing a proper maturing of the fruit.

Table 9.—*Effect of various sprays on composition of grapes (Virginia).*

Plat. No.	Spray used.	Copper sulphate in spray used.	Composition of grapes at picking time.		
			Reducing sugar.	Sucrose.	Acidity.
		Per cent.	*Per cent.*	*Per cent.*	*Cc. normal alkali per kilo.*
A	Bordeaux, 3-3-50	0.75	7.35	0.07	162
1	Pickering (A)	.64	10.52	.22	152
2	do	.38	8.57	.42	159
2b	Pickering (A) and rosin-fish-oil soap	.38	8.54	.10	157
3	Pickering (A)	.13	7.50	.10	155
5	Pickering (C)	.23	9.10	.28	152
7	do	.36	7.60	.20	151

The results (Table 9) naturally varied with the condition of the individual samples. The grapes from plat A, sprayed with standard Bordeaux mixture, showed the highest acidity and the lowest sugar content, while those from plat 1, treated with Pickering spray containing 0.64 per cent of copper sulphate, gave the highest content of sugar and a low acidity. Since the percentage of sugar increases and the percentage of acidity decreases during the ripening of grapes, no influence of the sprays in preventing a proper maturing of the fruit is indicated. On the contrary, an increase in the sugar content and a decrease of acid is evident in the Pickering-sprayed grapes, compared with those sprayed with Bordeaux. As no unsprayed grapes were analyzed, it is impossible to state whether or not the copper in the sprays exerted a stimulating action on the grapes.

The variation in the composition of the grapes sprayed with Pickering and Bordeaux may possibly be due to the greater availability of the copper in the Pickering sprays. The fact that more burning resulted from using the Pickering sprays than from using the Bordeaux sprays is evidence of a greater availability, or at least solubility, of the copper of the Pickering sprays. It has been suggested that the effect of the sprays on the composition of the fruit came through foliage injury.

Summary.

Pickering (A) and (C) sprays, containing 0.64, 0.36, and 0.38 per cent of copper sulphate, caused severe injury to the grape foliage and fruit after a hail storm which tore the leaves and injured the vines both at Vineland, N. J., and Vienna, Va., in 1916. Under similar conditions the Pickering sprays containing 0.23, 0.13, 0.115, and 0.065 per cent of copper sulphate caused less injury than the stronger Pickering sprays, but more injury than standard Bordeaux, 3–3–50, containing 0.75 per cent of copper sulphate.

The strongest Pickering spray, that employed on plat 1, controlled the black rot fully as well as the Bordeaux, 3–3–50, and the Pickering sprays containing 0.36 and 0.38 per cent of copper sulphate showed practically as effective control as the Bordeaux. The weaker Pickering sprays, containing 0.23 per cent of copper sulphate or less, did not control the black rot as well as the Bordeaux spray.

The yield of grapes was reduced by all of the Pickering sprays except the two weaker ones.

The copper of the Pickering sprays did not adhere to the grape leaves as well as the copper of the Bordeaux, 3–3–50. The averages of all the results obtained, including some not reported in the tables, show that where the Pickering sprays were applied with a power

sprayer as a fine mist (Vineland, N. J.) about one-half as much copper in proportion to that used in the spray adhered to the leaves as when standard Bordeaux was used. When the Pickering sprays were applied with a hand pump (Vienna, Va.), the ratio of copper retained on the leaves was still further reduced in the case of the Pickering sprays.

The use of rosin-fish-oil soap with one of the Pickering sprays proved advantageous in the Virginia tests, but not in the New Jersey tests.

Apparently the copper of the Pickering sprays exists in a more active and available form than the copper of the Bordeaux spray, as evidenced by the severe burning of the grape leaves. No differences were detected in the caustic action or in the adhesive properties of the Pickering (A) and (C) sprays. The caustic action and the fungicidal properties of the sprays made by the two formulas were apparently the same.

The Pickering sprays seem to be too caustic for spraying grapes. These sprays, however, may have a very definite use for the last application when this must be made late in the season after the berries are half grown. Bordeaux spray applied late in the season tends to remain on the berries, which is undesirable. Pickering sprays, however, are nonstaining.

APPLES.

Control of Fungous Diseases.

An orchard of Yellow Newtown (Albemarle Pippin) trees at Greenwood, Va., where bitter rot is prevalent, was selected for these experiments. The orchard was not well cultivated and was famous as a place for bitter rot.

In 1916.

Of the 27 trees in the orchard 12 were sprayed with Pickering sprays, 12 with standard Bordeaux, 4–5–50, and three were left unsprayed. The sprays were applied three times, June 23, July 13, and July 27. The Bordeaux spray was applied with a power sprayer each time. The Pickering sprays were applied the first time with a hand-pump sprayer and afterwards with a power sprayer. The results of this work are shown in Table 10.

TABLE 10.—*Effect of various sprays on bitter rot of apples (Virginia).*

Plat No.	Tree No.	Spray used.	Copper sulphate in spray.	Total apples.	Total apples with rot.	Apples with rot.	Dropped apples.	Apples injured by spray.	Defoliation.
1916.			*Per cent.*			*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
3	1	Pickering (A)	0.13	2,522	2,495	99			
3	2	do	.13	2,724	2,701	99			
3	3	do	.13	2,543	2,527	99			
4	1	do	.065	2,934	2,918	100			
4	2	do	.065	2,576	2,574	100			
4	3	do	.065	1,852	1,846	100			
5	1	Pickering (C)	.23	1,820	1,810	100			
5	2	do	.23	91	86	95			
5	3	do	.23	2,068	2,000	97			
6	1	do	.115	1,312	1,297	99			
6	2	do	.115	1,797	1,794	100			
6	3	do	.115	1,961	1,961	100			
Check	1			3,184	3,144	99			
Do	2			3,277	3,265	100			
Do	3			1,196	1,196	100			
	1	Bordeaux, 4–5–50	1.00	3,375	2,566	76			
	2	do	1.00	1,628	1,200	74			
	3	do	1.00	2,036	1,885	93			
1917.									
A_1		Pickering (A)	.50			.6	3.0	96.2	50
						.2	5.2		
A_2		do	.25			.3	3.0	82.3	50
						1.2	6.3		
A_3		do	.13			4.1	10.0	95.7	50
						.9	10.0		60
B_1		Pickering (C)	.50			.3	12.7	93.6	30
						.2	9.3		
B_2		do	.25			.5	45.5	98.0	18
B_3		do	.13			15.2	35.7		20
		Bordeaux, 2–2–50	.50			.1	12.3	25.0	15
		Bordeaux, 2–1–50	.50			.5	6.0	98.0	20
Check						10.3	10.5		
		Bordeaux, 4–4–50	1.0			.6	5.5	55.8	20
1918.									
		Pickering (C)	.58	5,724	200	3.5			
		Barium water	.60	2,594	50	2.0			
Check				3,736	736	17.0			
		Bordeaux, 4–4–50	1.00	4,552		.0			

Bitter rot was first seen in this orchard on July 10. On July 13, the time of the second spray application, there was a little bitter rot on two of the Bordeaux-sprayed trees and on one check tree. A small unhealthy tree in plat 5 showed the most bitter rot. On July 26, at the time of the third spraying, the following observations were made:

Plat 3.—All trees showed a little bitter rot.

Plat 4.—All trees showed a little bitter rot.

Plat 5. One tree showed a little bitter rot, and the other two trees a good deal of rot.

Plat 6. One tree showed rot at the top, while the other two were practically free from rot.

Bordeaux-sprayed plat.—Some trees showed no rot and others quite a little. On an average, the trees did not show as much rot as the check trees.

Check plat.—A good deal of rot was seen, more than on the other trees in the orchard.

As only two barrels of sound apples were obtained from the 27 trees, it is apparent that none of the sprays controlled the bitter rot in 1916. Although the apples from the trees sprayed with Bordeaux did not show as much rot as those from the trees sprayed with Pickering sprays or from the check trees, practically every apple from the 12 Bordeaux-sprayed trees was affected to some extent with bitter rot. The failure of any of the sprays to control the bitter rot may be explained by the fact that the rot was severe that season, as well as by the fact that no spray was applied to the trees after July 27.

IN 1917.

Three trees from each of three plats were treated with Pickering (A) and (C) sprays, containing 0.50, 0.25, and 0.13 per cent of copper sulphate. Bordeaux, 4–4–50, was employed as the standard spray. Two trees were sprayed with Bordeaux, 2–2–50, and two with Bordeaux, 2–1–50, sprays, in order to determine the effect of decreasing the lime on the fungicidal action of the copper. Several unsprayed trees were left as controls. The sprays were applied with a power sprayer four times, June 4, June 22, July 9, and August 2. On August 2, because of injury caused by the sprays, the spray was applied to but one tree of plats A_1, A_2, A_3, B_1, B_2, B_3, and to but one of those sprayed with Bordeaux, 2–1–50. On August 30, counts were made of all dropped fruit. All fruit on the trees was picked between September 14 and 18, and counted for rot and for a late type of Bordeaux injury or russeting which developed between August 30 and September 13. The results are shown in Table 10.

Scarcely any bitter rot was present in the orchard in 1917. Consequently, the results prove very little concerning the relative fungicidal value of the sprays tested. On plat B_3, the tree sprayed with Pickering solution was the only one of the sprayed trees which showed any amount of rot, the other two trees of that plat being practically free from rot.

IN 1918.

Pickering (C) spray and a barium-water spray, similar to the one used on potatoes with excellent results (page 11), were used on Cheese apple trees. Ten gallons of the barium-water spray were prepared by dissolving 8 ounces of barium hydrate in 9 gallons of water and adding 2 quarts of copper sulphate stock solution (1 pound per gallon), diluting to 10 gallons with water, and stirring thoroughly. The Pickering (C) spray was prepared according to the directions given on page 7. A Bordeaux, 4–4–50, spray was the standard spray. Two trees were sprayed with the Pickering spray, two with the barium-water spray, and two with standard Bordeaux, while one tree was left unsprayed. The sprays were applied with a power sprayer on June 14, June 28, July 26, and August 13.

At the time of the third spraying it was noticed that three or four apples on the check tree were infected with bitter rot, whereas the sprayed trees seemed to be entirely free from it. On August 13, the date of the fourth application, one or two apples on the Pickering-sprayed, barium-water-sprayed, and Bordeaux-sprayed trees were infected with bitter rot, while the check tree showed a fairly large amount of rot.

At the time of picking very little bitter rot was found on any of the trees. The Bordeaux spray gave 100 per cent protection from bitter rot. The barium-water spray gave a better control of bitter rot than the Pickering spray. The 1918 results (Table 10) are inconclusive because of the small number of apples infected with bitter rot on the sprayed trees.

Adherence of Copper from Various Sprays to Leaves.

in 1916.

One set of leaves was gathered from the sprayed and check trees on July 12, 13 days after the second spraying, and a second set on July 13, three hours after the third spray had been applied. The outlines of these leaves were immediately traced on paper, and later measured with a polar planimeter. The area of each set of 50 leaves was calculated, but one side of the leaves being used in the calculation. Later the leaves were dried, and the copper determined in each set (Table 11).

Table 11.—*Adherence of copper from various sprays to apple leaves (Virginia).*

Plat No.	Spray used.	Copper sulphate in spray used.	Time between spraying and gathering of leaves.	Copper adhering to leaves.			
				Parts per million (dry basis).	Parts per million per 0.1 per cent of $CuSO_4$ in spray.	Mg. per square meter of leaf surface.	Mg. per square meter of leaf surface per 0.1 per cent $CuSO_4$ in spray.
1916.		*Per cent.*	*Days.*				
.....	Bordeaux, 4-5-50	1.00	13	425	42.5	26.0	2.6
3	Pickering (A)	.13	13	59	45.4	1.3	1.0
4	do	.065	13	90	138.5	9.3	14.3
5	Pickering (C)	.23	13	248	107.8	25.6	11.1
6	do	.115	13	77	67.0	2.2	1.9
.....	Bordeaux, 4-5-50	1.00	¼	3,150	315.0	266.6	26.7
3	Pickering (A)	.13	¼	260	200.0	16.0	12.3
4	do	.065	¼	185	284.6	10.2	15.7
5	Pickering (C)	.23	¼	646	280.9	15.9	6.9
6	do	.115	¼	249	216.6	20.3	17.7
Check			¼				
1917.							
.....	Bordeaux, 4-4-50	1.00	15	644	64.4	33.8	3.4
Check			15	6.6		.3	
.....	Bordeaux, 2-1-50	.5	15	316	63.2	15.5	3.1
.....	Bordeaux, 2-2-50	.5	15	255	51.0	12.5	2.5
A_1	Pickering (A)	.50	15	206	41.2	10.5	2.1
A_2	do	.25	15	146	58.4	6.5	2.6
A_3	do	.125	15	62	49.6	3.0	2.4

TABLE 11.—*Adherence of copper from various sprays to apple leaves (Virginia)*—Contd.

Plat No.	Spray used.	Copper sulphate in spray used.	Time between spraying and gathering of leaves.	Copper adhering to leaves.			
				Parts per million (dry basis).	Parts per million per 0.1 per cent of $CuSO_4$ in spray.	Mg. per square meter of leaf surface.	Mg. per square meter of leaf surface per 0.1 per cent $CuSO_4$ in spray.
1917.		*Per cent.*	*Days.*				
B_1	Pickering (C)	0.50	15	362	72.4	16.5	3.3
B_2	do	.25	15	136	54.4	7.5	3.0
B_3	do	.125	15	52	41.6	3.0	2.4
	Bordeaux, 4-4-50	1.00	25	955.9	95.6	46.8	4.7
Check			25	3.2		0.15	
	Bordeaux, 2-1-50	.5	25	374.8	75.0	21.1	4.2
	Bordeaux, 2-2-50	.5	25	595.2	119.0	32.3	6.5
A_1	Pickering (A)	.50	25	800.9	160.2	37.4	7.5
A_2	do	.25	25	445.8	178.0	22.2	8.9
A_3	do	.125	25	126.0	101.0	5.6	4.5
B_1	Pickering (C)	.50	25	683.3	136.7	33.6	6.7
B_2	do	.25	25	390.0	156.0	19.3	7.7
B_3	do	.125	25	172.3	138.0	9.4	7.5
1918.							
A	Pickering (C)	.58	0	2,250	390		
B	Barium water	.60	0	3,250	542		
C	Bordeaux, 4-4-50	1.00	0	4,350	435		
Check			0	6			
A	Pickering (C)	.58	28	1,450	250		
B	Barium water	.60	28	2,400	400		
C	Bordeaux, 4-4-50	1.00	28	4,150	415		
Check			28	20			

The figures for the copper found on the leaves picked July 26 (13 days after spraying) show that the leaves sprayed with standard Bordeaux held the most actual copper. Calculated per 0.1 per cent of copper sulphate present in the sprays used, however, the leaves sprayed with the Pickering sprays held twice as much copper when calculated by weight and three times as much when calculated by area as did the leaves sprayed with Bordeaux. The figures for the copper found on the leaves picked on July 27 (three hours after the third spraying) are highest in the case of Bordeaux-sprayed trees. The results are much higher for the Bordeaux- than for the Pickering-sprayed leaves when expressed by area and slightly higher when expressed by weight. Evidently, in proportion to the copper sulphate content, the Bordeaux sprays adhered better to the leaves directly after application, although the copper of the Pickering sprays adhered to the leaves in a higher ratio than Bordeaux for the 13-day period tested.

IN 1917.

Two sets of 50 leaves were collected in duplicate from the trees receiving the different sprays, the first on July 7, two weeks after the second spraying, and the second on August 3, nearly four weeks after spraying. The leaves were analyzed for copper, the results of which appear in Table 11.

Of the leaves picked two weeks after spraying, those receiving the Bordeaux, 4-4-50, held the most copper. The leaves sprayed with Bordeaux, 2-1-50, held more copper than those on which 2-2-50 spray was used. No important differences were noted between the adhesive properties of the copper of the Pickering (A) and (C) sprays. In three cases the leaves treated with the Pickering sprays held practically the same amount of copper per 0.1 per cent of copper sulphate used as the leaves sprayed with Bordeaux, 4-4-50. The other three Pickering sprays gave lower results. The results for copper on the leaves by area were slightly in favor of the Bordeaux spray.

The analyses of the second set of leaves, gathered nearly four weeks after spraying, showed the most copper on the Bordeaux-sprayed leaves, although the leaves from plat A_1 sprayed with Pickering spray held 800 parts of copper per million. Contrary to the results recorded on page 19, the leaves receiving the Bordeaux, 2-1-50, spray did not hold as much copper as those sprayed with the Bordeaux, 2-2-50.

All of the Pickering-sprayed leaves held more copper than the Bordeaux-sprayed leaves per unit of copper sulphate in the spray applied, indicating that per unit of copper sulphate present in the spray the copper of the Pickering sprays adheres to apple leaves in larger proportions than the copper of standard Bordeaux spray.

IN 1918.

Leaves from the trees sprayed with Pickering, barium water, and Bordeaux and from the check tree were collected on June 28, just after spraying, and July 26, 1918, 28 days after spraying, and analyzed for copper. The results appear in Table 11.

As the period from the time of the collection of the first set of leaves until the collection of the second set was very dry, about as much copper was found on the second set as on the first set of leaves. The results for the leaves picked immediately after spraying, per 0.1 per cent of copper sulphate present in the sprays, are highest for those receiving the barium-water spray. The Bordeaux-sprayed and the Pickering-sprayed leaves gave practically the same results. The results for the leaves picked 28 days after spraying from Pickering-sprayed trees are low, while those for the barium-water- and the Bordeaux-sprayed leaves are practically identical.

INJURY TO LEAVES AND FRUIT.

IN 1916.

Although the season was wet and sultry, only a trace of injury to the leaves and fruit was noted on the trees treated with Pickering spray. This injury had no practical significance. The Bordeaux spray did not injure the leaves or fruit.

IN 1917.

On June 20 a severe hail storm injured the leaves. On June 21, at the time of the second spray application, some burning of the leaves on the trees treated with the Pickering sprays was noted, as well as a slight burning of the leaves on the trees sprayed with Bordeaux, 4–4–50, 2–2–50, and 2–1–50. The burning caused by the Pickering sprays was far more noticeable than that due to the Bordeaux sprays, and varied among the trees of the same plat. Little difference was evident between the Pickering (A) and (C) sprays with respect to caustic properties on this date. On August 2 the leaves of the trees on plats A_1, A_2, and B_1 showed the most injury. Those sprayed with Bordeaux, 2–1–50, also showed severe burning of the leaves. The trees in the upper portion of the orchard which had been sprayed with standard Bordeaux spray showed marked burning of the leaves, while those sprayed with the standard Bordeaux in the lower part of the orchard showed but slight burning of the leaves.

Part of the Pickering-sprayed trees received only three applications, while the others were sprayed four times. The fourth application of the Pickering sprays produced no additional injury.

All the Pickering sprays reduced the yield of fruit, because of the defoliation occurring during July and August. The fruit on the 18 trees receiving the Pickering sprays was under size. The yield was reduced to a greater extent on the trees sprayed with the Pickering (A) sprays than on those sprayed with the Pickering (C) sprays. Defoliation also caused a reduction in the yields of the Bordeaux-sprayed trees and of those sprayed with Bordeaux, 2–2–50 and 2–1–50. Pickering (C) sprays produced about the same percentage of defoliation as the Bordeaux sprays, while Pickering (A) sprays caused much more defoliation. The figures in Table 10 do not show any influence of the sprays on the percentage of apples that dropped from the trees, which was very high on plats B_2 and B_3. The A series of sprays, which injured the leaves severely and caused the greatest amount of spray injury, showed a low percentage of drops. The number of drops (10 per cent) from the check trees and the lack of increase of drops from the trees treated with the Pickering sprays used on plats A_1 and B_1, the two strongest of each formula with respect to percentage of copper sulphate, over those from the check trees lead to the conclusion that the high percentage of drops for the sprayed trees on plats B_2 and B_3 was not due to the sprays used.

Spray or late Bordeaux injury of apples.—Early in September a specking of the fruit on all the sprayed trees was noticed. This injury, known as spray or late Bordeaux injury, consisted of red spotting usually surrounding a lenticel, and generally found on the exposed side of the apple. On some apples the injury was so severe

as to cover the entire exposed cheek with a deep red blush, due to the coalescence of individual spots. This type of injury was common in this locality, particularly in those orchards which had been thoroughly sprayed with Bordeaux. It was most severe on the trees which had received the Pickering (A) spray, a little less severe on the trees treated with Pickering (C) spray, and very apparent on the Bordeaux-sprayed trees. The spotting or late Bordeaux injury, shown on all the sprayed trees, reduced the value of the 1917 crop. The unsprayed trees yielded the best fruit. The reduction of yield due to bitter rot was practically negligible.

IN 1918.

At the time of the third spraying, July 26, possibly 5 per cent of the leaves on the trees treated with the barium-water spray and some on the Pickering-sprayed trees and on the Bordeaux-sprayed trees showed a yellowing. The dry weather and heat during the previous four weeks may have been responsible for this yellowing which was not serious in any case. No injury to the apples was observed. At the time of picking no foliage injury of any consequence was observed on any of the plats. A brief outline of the theories advanced to explain the injury to foliage which frequently results from the application of copper sprays is given on page 27.

No results to show whether the sprays increased or decreased the yield are obtainable. The only available figures on yield are the records of the number of apples secured in connection with the bitter-rot counts, which are from but one tree of each plat.

SUMMARY.

In 1916 practically all of the fruit from the trees treated with Pickering and Bordeaux sprays and from the check trees was infected with bitter rot, which made it impossible to determine the relative efficacy of the Pickering sprays. Slight injury to the leaves and fruit on the Pickering-sprayed trees was noticed.

In 1917, Pickering (A) sprays containing 0.12, 0.25, and 0.5 per cent of copper sulphate injured apple leaves, and caused late Bordeaux injury to the fruit. Pickering (C) sprays of the same strengths produced less injury. Standard Bordeaux, 4–4–50, spray, containing 1 per cent of copper sulphate, also injured the leaves and russeted the fruit, although not as severely as the Pickering (C) spray. But little bitter rot was found on any of the Pickering- or Bordeaux-sprayed or check trees. Hence no control test of the sprays was obtained.

In 1918 no injury to the leaves or fruit resulted from the use of a Pickering (C) spray containing 0.58 per cent of copper sulphate,

from a barium-water spray containing 0.6 per cent of copper sulphate, or from standard Bordeaux, 4–4–50. The amount of bitter rot on the sprayed trees was so small that no definite control results were obtained.

The data on the control of bitter rot by Pickering (A) and (C) sprays are rather limited, notwithstanding the fact that the experiments extended over three seasons. However, 0.5 per cent of copper sulphate present in either Pickering (A) or (C) spray gave indications of satisfactory control of fungous diseases.

The Pickering (A) spray is too caustic for use on the apple. While less caustic than Pickering (A) sprays, the Pickering (C) sprays seem to be more caustic than standard Bordeaux. It is apparent that these sprays are more caustic than standard Bordeaux, and can not be used on the apple.

The barium-water spray was tested but one season on the apple. While the results were satisfactory with respect to the absence of injury, so little bitter rot was present on any of the trees that season that no definite control results were obtained.

Additional experiments are necessary to determine whether a Pickering spray containing more limewater than is required in Formula C and the barium-water spray may be safely and efficiently used as a fungicide on the apple.

CRANBERRIES.

Control of Fungous Diseases.

IN 1917.

Two Pickering (A) sprays and two Pickering (C) sprays were tested on Centennial cranberries in 1917 at Hanover Farms, N. J. The percentage of copper sulphate in the four sprays varied from 0.32 to 0.62. In addition, Bordeaux, 2½–1¼–50, 2½–2½–50, and 4–3–50, sprays were used. The first two Bordeaux sprays were taken for the purpose of comparing the different amounts of lime in a Bordeaux spray with the amount in a Pickering spray of the same copper sulphate content (0.64 per cent).

The sprays were applied to small plats, 132 feet long and 8¼ feet wide, with a hand-pump sprayer, four times during the season, June 14 (three or four days before full bloom), June 27 (10 days after full bloom), July 13, and July 30. Rosin-fish-oil soap, at the rate of 2 pounds to 50 gallons, was mixed with all the sprays. The berries were picked September 15 and sorted for rot soon afterwards.

TABLE 12.—*Effect of various sprays on rot and yield of cranberries (New Jersey).*[1]

Plat No.	Spray used.	Copper sulphate in spray used.	Total yield.			Yield per acre (calculated).	
			All berries.	Rotten berries.		All berries.	Sound berries.
1917.		*Per ct.*	*Pounds.*	*Pounds.*	*Per ct.*	*Bushels.*	*Bushels.*
1	Pickering (A)	0.32	67¼	.....	4.8	.....	80
2	Pickering (C)	.40	57	.....	6.5	.....	66½
3	do	.54	55⅝	.....	5.4	.....	66
4	Pickering (A)	.62	53½	.....	5.8	.....	62½
5	Bordeaux, 4–3–50	1.00	50¼	.....	5.6	.....	59⅝
6	Bordeaux, 2¼–1¼–50	.64	73⅜	.....	4.4	.....	88½
7	Bordeaux, 2½–2½–50	.64	59⅛	.....	5.1	.....	70⅜
8 (check)			78½	.....	12.0	.....	86¼
A	Pickering (A)	.6	19⅛	⅛	4.2	.....	.....
B	Bordeaux, 4–3–50	1.00	19⅝	⅛	2.8	.....	.....
1918.							
1	Sal soda and rosin-fish-oil soap, 4–5–50.	1.00	54⅜	6½	11.9	136¾	120½
2	Sal soda and fish-oil emulsion, 4–5–50.	1.00	68½	5	7.3	171¼	158½
3 (check)			41½	6¼	15.1	207½	176⅜
4	Barium water and rosin-fish-oil soap.	.6	80½	13	16.1	201¼	168¾
5	Pickering (C) and rosin-fish-oil soap.	.6	107½	20½	19.1	268	216⅞
6	Pickering (A) and rosin-fish-oil soap.	.6	94½	20½	20.8	235½	184¼
7 (check)			38	26½	69.7	190	57½
8	Bordeaux, 4–3–50, and rosin-fish-oil soap.	1.00	74½	12	16.2	185½	155½
9	Bordeaux, 4–2–50, and rosin-fish-oil soap.	1.00	59½	5⅞	9.7	148¾	134¼
10	Bordeaux, 4–1–50, and rosin-fish-oil soap.	1.00	64½	8¼	12.8	161½	140½

[1] All the cranberries tested were of the Centennial variety, except those on plats A and B, which were Early Black.

The percentage of rot found on the berries from all of the sprayed plats (Table 12) was so small that it was impossible to differentiate between the sprays with respect to their fungicidal value. The check plat showed but 12 per cent of rot. The Bordeaux, 2½–1¼–50, spray gave the best results for control of rot, but all of the other sprays were almost as good. On the large plats (A and B) 4.2 per cent of rot was found for berries treated with the spray resembling a Pickering spray and 2.8 per cent for those treated with Bordeaux. While the data favor the standard Bordeaux spray, the figures are small.

Two large plats (A and B) of Early Blacks were sprayed with a power sprayer, one receiving Bordeaux, 4–3–50, the regular spray used on cranberries at Hanover Farms, and the other a spray resembling a Pickering spray of 0.6 per cent copper sulphate content, made by dissolving in water an amount of lime paste calculated from titrations to be sufficient to combine with the copper sulphate used. The results thus obtained are not comparable with those obtained from plats 1 to 8 (Table 12).

IN 1918.

Ten small plats of Centennial berries at Hanover Farms, N. J., were sprayed with a barrel-pump sprayer on June 11 (three or four days

before full bloom), June 25 (10 days after full bloom), July 24, and August 12. The small plats were separated by four-foot paths over which the spray apparatus was drawn, thus protecting the berries on the sprayed plats from injury like that received in 1917. The vines on plats 5 and 6 were heavier than those on the other plats. Pickering (A) and (C) sprays, a barium-water spray, two sal-soda (Na_2CO_3) sprays, and three sprays of the Bordeaux type, made with 1 per cent of copper sulphate and varying amounts of lime, were employed (Table 12). The sal-soda (Na_2CO_3) and fish-oil-emulsion spray was prepared by shaking together 1 ounce of water and an equal amount of fish oil until emulsified, and then stirring it into the spray. The barium-water spray was prepared by the use of barium hydrate in place of lime (p. 16). The Pickering (C) spray was made with an excess of limewater, and the Pickering (A) spray with just the amount of limewater required to neutralize all the copper sulphate present (p. 3).

As shown by the figures for rotten berries, 15.1 and 69.7 per cent for the check plats (Nos. 3 and 7), the amount of rot varied greatly. The lowest percentage of rotten berries was obtained on plat 2, where sal-soda and fish-oil-emulsion spray was used.

The following notes were taken on September 5:

Plat. 1.—The sal-soda spray resembles the Bordeaux, 4–3–50, spray used on plat 8.

Plat 2.—The berries look sound. More spray is seen on berries than on those in plat 1. It occurs in isolated spots or freckles, rather than in a continuous layer, as is the case with the spray on plat 1.

Plat 3.—Berries are quite sound. Not over 5 per cent of rot is visible.

Plat 4.—Spray is seen distinctly over entire plat. It is the only plat that looks blue at a distance. Good protection is afforded, although there is more rot than on plats 1 and 2. The spray shows regularly on the berries, but is not of uniform density. The berries with spray have a festooned appearance, as if each drop of spray on drying was thickest at the periphery.

Plat 5.—But few rotten berries seen. Spray shows plainly in spots.

Plat 6.—Same as plat 5.

Plat 7.—Estimated 50 per cent rot.

Plat 8.—Berries very sound. A little more spray visible than on either plat 5 or 6.

Plat 9.—Generally like plat 8. Spray somewhat more apparent. Vines not quite as thick as on most of the other plats.

Plat 10.—Spray shows about like that on plat 9. The northern end of the plat is poor land and shows more rot. Rest of plat is very sound.

More spray was observed on the plat treated with Bordeaux, 4–3–50, than on those sprayed with the Pickering sprays. It is difficult to explain the results obtained with the barium-water spray, which, judging from the figures for rot control, produced no effect. This spray gave an excellent control of fungous diseases on potatoes, as compared with a Bordeaux, 5–5–50. Pickering (A) and (C) sprays on plats 5 and 6, where the vines were very dense, showed practically identical fungicidal power. The sprays used on plats 8, 9, and 10 showed good control of rot. From a comparison of results with sprays used on plats 8, 9, and 10, it is impossible to determine the influence of the different amounts of lime on the fungicidal properties of the 1 per cent copper sulphate present in the three sprays.

Included in the 1918 tests were three commercially-sprayed plats, treated with a Pickering (C) spray containing 0.6 per cent of copper sulphate, a Bordeaux spray made with 0.6 per cent copper sulphate, and a Bordeaux, 4–3–50, containing 1 per cent copper sulphate, such as is regularly employed for spraying cranberries at Hanover Farms. Two hundred gallons of each spray were made and applied with the power spray apparatus to Early Blacks. Rosin-fish-oil soap was used with all three sprays. The sprays were applied three times, June 13, July 3, and July 24. Very little rot was seen on any of the plats, and at the time of picking no differences in control of rot on the three plats were evident. No check plat was employed.

Yield.

In 1917.

The calculation of the results for yield of the Centennial berries (Table 12) was complicated by injury to the berries due to drawing the spray apparatus over the vines four times. The high figure for yield on the check plat is in part explained by the fact that none of the berries on this plat were crushed by the spray cart. Unavoidable irregularities occur in the yields of all plats of cranberries of any size. The yield results on Early Blacks are so close that no conclusions can be drawn as to the influence of the sprays on the yields of berries.

In 1918.

No results which show the influence of the sprays on the yields of cranberries are available.

Adherence of Copper from Various Sprays to Leaves.

In 1917.

Samples of cranberry leaves were gathered on July 10, two weeks after the third spray had been applied, and on September 4, five weeks after the fourth spraying, and analyzed (Table 13).

TABLE 13.—*Adherence of copper from various sprays to cranberry leaves (New Jersey).*

Plat No.	Spray used.	Copper sulphate in spray used.	Time between spraying and gathering.	Amount of copper.	
				Parts per million (dry basis).	Parts per million per 0.1 per cent of copper sulphate in spray.
1917.		*Per cent.*	*Days.*		
1	Pickering (A)	0.32	14	110.8	35
2	Pickering (C)	.405	14	140.2	35
3	do	.54	14	167.2	31
4	Pickering (A)	.64	14	166.2	26
5	Bordeaux, 4–3–50	1.00	14	680.2	68
6	Bordeaux, 2½–1½–50	.64	14	407.8	64
7	Bordeaux, 2½–2½–50	.64	14	385.4	60
8 (check)				32.6	
1	Pickering (A)	.32	35	80.0	25
2	Pickering (C)	.405	35	100.7	25
3	do	.54	35	146.7	27
4	Pickering (A)	.64	35	131.3	21
5	Bordeaux, 4–3–50	1.00	35	429.0	43
6	Bordeaux, 2½–1½–50	.64	35	138.0	21
7	Bordeaux, 2½–2½–50	.64	35	323.4	51
8 (check)					
1918.					
1	Sal soda and rosin-fish-oil soap	1.0	0	1,200	120
2	Sal soda and fish-oil emulsion	1.0	0	1,300	130
4	Barium water and soap	.6	0	1,100	183.3
5	Pickering (C) and soap	.6	0	1,100	183.3
6	Pickering (A) and soap	.6	0	1,400	233.3
7 (check)				47	
8	Bordeaux, 4–3–50, and soap	1.0	0	1,600	160
9	Bordeaux, 4–2–50, and soap	1.0	0	1,800	180
10	Bordeaux, 4–1–50, and soap	1.0	0	1,600	160
1	Sal soda and rosin-fish-oil soap	1.0	28	330	33
2	Sal soda and fish-oil emulsion	1.0	28	380	38
4	Barium water and soap	.6	28	210	35
5	Pickering (C) and soap	.6	28	630	105
6	Pickering (A) and soap	.6	28	370	61.7
7 (check)				17	
8	Bordeaux, 4–3–50, and soap	1.0	28	840	84
9	Bordeaux, 4–2–50, and soap	1.0	28	1,000	100
10	Bordeaux, 4–1–50, and soap	1.0	28	860	86

The leaves sprayed with Bordeaux held a higher percentage of copper than those sprayed with the Pickering sprays, indicating that the extra lime of the Bordeaux spray, at least where rosin-fish-oil soap was used, is an important factor in increasing the adhesive properties of the spray on cranberry leaves. Possibly the copper of the Pickering sprays was more efficient as a fungicide per unit of copper present in the sprays than that of the standard Bordeaux spray, although the copper of the Pickering sprays did not adhere to the leaves as well as that of the Bordeaux sprays. The results for control of rot favor this view. The percentage of rotten berries (Table 12) does not speak particularly well for the sprays used on Plats 5 and 7, in spite of the fact that the leaves receiving these sprays retained the largest amounts of copper (Table 13). The results given in Table 13 show nothing concerning the distribution of the copper on the leaves or the form and efficacy of the copper on the leaves.

IN 1918.

One set of sprayed cranberry leaves was gathered for analysis for copper on June 25, directly after the sprays had been applied, and a

second set on July 24, four weeks after the last sprays had been applied (Table 13).

The most actual copper was found on the leaves sprayed with Bordeaux containing 1 per cent of copper sulphate (plats 8, 9, and 10). Calculated per 0.1 per cent of copper sulphate present in the sprays, the leaves from plats 4, 5, and 6, sprayed with the two Pickering sprays and the barium-water spray, and gathered directly after the sprays had been applied, gave the highest results. Of the leaves gathered four weeks after spraying, those treated with the Bordeaux sprays (plats 8, 9, and 10) and with the Pickering sprays (plats 5 and 6) gave the highest proportional results. The barium-water spray and the two sprays made with sal soda did not adhere to the leaves for the four-week period as well as the sprays made with lime. The percentage of rotten berries found on the two plats sprayed with the sal-soda sprays was low, in spite of the relatively small amounts of copper adhering to the leaves at the time of analysis. Apparently, therefore, the amount of copper adhering to a leaf is not necessarily a criterion of its protection from fungous diseases.

Injury to Leaves and Fruit.

No caustic action of any of the sprays was noted in either 1917 or 1918.

Summary.

None of the sprays tested injured the leaves or berries.

The Pickering (A) and (C) sprays were equally effective in controlling fungous diseases. Pickering (A) and (C) sprays prepared with 0.6 per cent of copper sulphate seemed to give as effective control of fungous diseases on cranberries as Bordeaux, 4–3–50, containing 1 per cent of copper sulphate, although this was not definitely proven.

Practically the same percentage of copper was present on the cranberry leaves treated with Pickering spray as on those sprayed with standard Bordeaux, rosin-fish-oil soap being used with all the sprays.

Additional tests with the Pickering, barium-water, and sal-soda sprays are necessary to obtain conclusive results.

SUGGESTIONS FOR THE PREPARATION OF PICKERING SPRAY ON A COMMERCIAL SCALE.

The following procedure is recommended for the preparation on a commercial scale of a Pickering (A) spray containing 0.7 per cent of copper sulphate:

STOCK SOLUTION OF COPPER SULPHATE (BLUESTONE OR BLUE VITRIOL).

Suspend 50 pounds of commercial crystalline copper sulphate in a gunny sack in 20 or 30 gallons of water in a clean barrel over

night, placing the copper sulphate just beneath the surface of the water. This may be conveniently done the evening before the spray is to be applied. Remove the gunny sack, stir the solution of copper sulphate with a wooden paddle, make to 50 gallons with water, and stir again. Keep the barrel or container covered. The barrel or container must not leak. The solution thus prepared contains 1 pound of copper sulphate per gallon. Smaller amounts of the copper sulphate may be dissolved, using the same proportions of copper sulphate and water

SATURATED LIMEWATER.

Place 2 pounds of unslaked lime of a good grade in a clean barrel or other wooden container, sprinkle with a little water, and let stand. In a few minutes, when the lime crumbles, add 2 or 3 quarts of water. Stir the lime and water until a smooth paste is formed, adding a little more water if needed. Finally, fill the barrel and stir six or eight times, allowing the insoluble particles of the lime to settle after

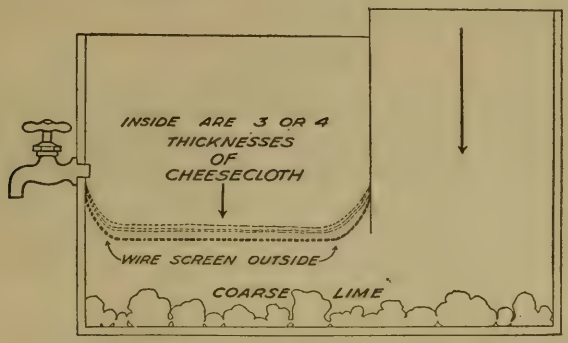

FIG. 1.—Apparatus for filtering limewater.

each stirring. Then cover and let stand until used. The limewater may be drawn from the barrel by means of a faucet placed 3 or 4 inches from the bottom. The limewater should be passed through a strainer (fig. 1) before it is allowed to flow into the mixing tank. If preferred, the clear limewater may be siphoned off from the top of the barrel directly into the mixing tank.

In making limewater for spraying on a commercial scale, several pounds of lime may be slaked in a large tank, water added, and the mixture stirred by means of a mechanical stirrer for 5 or 10 minutes. The clear limewater may be drawn from the top of the tank almost immediately by arranging a float with attached hose. If from 15 to 20 minutes are allowed for the lime particles to settle, the clear limewater may be drawn from a spigot placed 6 or 8 inches from the bottom of the tank. If desired, slaked lime may be placed in barrels, allowing about 4 pounds of paste to a barrel, water added, and the mixture in each barrel stirred six or eight times in turn. The suspended particles will settle in about 10 minutes, when the clear

limewater may be drawn off by suction through a hose into the mixing tank or barrel.

In making saturated limewater, 2 pounds of unslaked lime, or 4 pounds of lime paste, to 50 gallons of water are sufficient.

MIXING.

Add 23.1 quarts of the standard copper sulphate solution (1 pound to a gallon) to a 100-gallon tank containing 93.78 gallons of clear saturated limewater, and stir for 1 minute. Lead arsenate or calcium arsenate may then be added if desired, and 0.42 gallon of water to make the volume to 100 gallons.

The method of preparing limewater is the principal distinction between making the Pickering and the standard Bordeaux sprays.

In the experience of the writer, the Pickering sprays are readily prepared, in much less time than many of the proprietary pastes which dissolve with difficulty, and take but little more time than the standard Bordeaux sprays require.

SUMMARY.

Experiments covering three seasons were conducted with Pickering (A) and (C) sprays, made to contain from 0.06 to 0.70 per cent of copper sulphate. The efficacy of these sprays was compared with that of standard Bordeaux mixtures containing from 0.75 to 1.25 per cent of copper sulphate. The investigation was carried out under American field conditions, in regions where certain fungous diseases are most severe.

The strongest Pickering sprays, those containing from 0.6 to 0.7 per cent of copper sulphate, controlled fungous diseases on potatoes and cranberries very effectively. Their control of fungous diseases on grapes and apples was not definitely determined, the results being complicated by burning or other injury to the foliage and fruit. Pickering sprays containing less than 0.6 per cent of copper sulphate were not effective as fungicides for potatoes and probably not for cranberries. No difference between the efficacy of the Pickering (A) sprays and that of the Pickering (C) sprays was observed. The results of the tests made on potatoes indicated that per unit of copper present the Pickering sprays were twice as effective as the Bordeaux mixture. No evidence, however, was found to substantiate the claims of Bedford and Pickering (3, 4) that they were from 12 to 15 times as efficient as the standard Bordeaux sprays. As long as enough lime to combine with the copper was present, the reduction of the lime content of Bordeaux sprays did not alter their fungicidal value.

Increased yields of tubers were obtained on plats of potatoes treated with Bordeaux and with the stronger Pickering sprays, in-

dicating that these sprays exerted similar stimulating and protective action on potato plants.

The adhesive properties of Pickering sprays varied with the foliage to which they were applied. They adhered to potato and cranberry leaves in practically the same degree as the standard Bordeaux, to apple leaves in a somewhat higher proportion, and to grape leaves in a lower proportion.

No injurious effects followed the application of Pickering sprays to potatoes in Maine or to cranberries in New Jersey. The sprays, however, proved to be too caustic for use on the apple in Virginia or on grapes in New Jersey and Virginia. Pickering sprays can not be used on tender foliage.

Barium-water sprays of the Pickering type, made with barium hydrate instead of lime and containing 0.7 per cent of copper sulphate, proved very successful as a fungicide for potatoes. Such a spray containing 0.6 per cent of copper sulphate did not injure the foliage or fruit of the apple tree.

These results are presented as the basis for further studies to be conducted in various parts of the country. It is believed that from this material agricultural experiment stations and other agencies will be able to devise formulas for sprays for certain crops containing less copper sulphate than standard Bordeaux, which will prove just as effective as the more expensive spray.

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